MAGNETIC SOUTH PTY LTD

GROUNDWATER IMPACT ASSESSMENT
GEMINI COAL PROJECT

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1.0 INTRODUCTION

Magnetic South Pty Ltd is the project proponent and the applicant for the Mining Lease (ML) and Environmental authority (EA) to develop the Gemini Project, a greenfield open cut mine to produce Pulverised Coal Injection (PCI) coal and Coking Coal products for export for steel production. The Project term is anticipated to be 25 years from grant of the ML with this term including initial construction, mine operation and rehabilitation activities. Mining at the Gemini Project is projected to occur over approximately 20 years as a truck and shovel operation at an average of 1.8 million tonnes per annum (Mtpa) ROM coal.

The Project is located approximately 150 km to the east of Rockhampton and 8 km west of the town of Dingo and is accessed by the Capricorn Highway, which transects the northern part of the tenement (Figure 1-1).

This report provides a comprehensive assessment of:

- The regional and mine-scale geology and hydrogeology;
- The installation of a groundwater monitoring bore network that has been designed to provide water level and water quality data from all groundwater units at site;
- A program of hydraulic testing that has been carried out on the groundwater monitoring bores at site in order to provide site-specific hydraulic conductivity data for groundwater modelling;
- Water level and water quality data obtained to date from the site groundwater monitoring bores;
- Regional groundwater occurrence and use;
- A conceptual groundwater model for the site; and,
- Groundwater modelling that has been undertaken to provide predictions of:
    - the rate of groundwater inflow to the mined voids; and
    - the extent of groundwater level impacts from mining, which are used to provide prediction of the potential for impact on sensitive environmental receptors such as landholder bores and groundwater dependent ecosystems (GDEs).

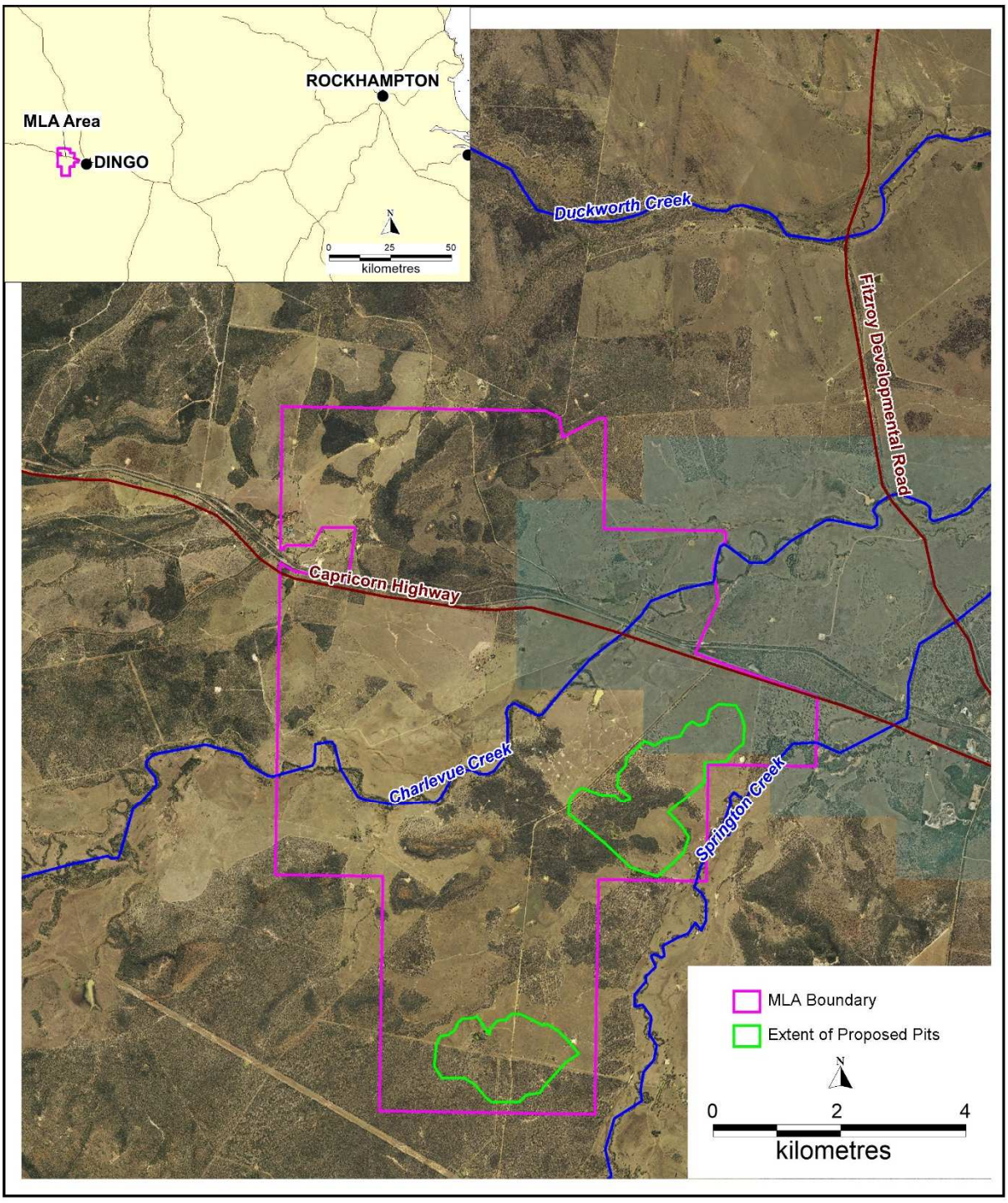

Figure 1-1: Project Location

2.0 CLIMATIC DATA

The climatic description of the region in which the project site is located has been compiled using data from the DNRM SILO Data Drill. The Data Drill accesses grids of climate data available from surrounding Bureau of Meteorology (BoM) point observations and then creates interpolated climate values for the requested location. The SILO climate data was obtained for coordinates that correspond to the approximate centre of the Gemini Project site.

Summary data for rainfall and evaporation is shown in Table 2-1 and indicates that:

- Mean annual rainfall for the site is approximately 678 mm; and,
- Mean annual evaporation is approximately 2024 mm and exceeds rainfall for every month of the year.

The data has been utilised to produce a climatograph for the Gemini Project site (Figure 2-1), which shows that:

- rainfall is highly seasonal, with the dry season from April to September-October, and a wet season from November through to March;
- The coldest month of the year is July, with a mean minimum temperature of 7.7 ºC and a mean maximum temperature of 23.2 ºC; and,
- The hottest month of the year is January, with a mean minimum temperature of 21.6 ºC and a mean maximum temperature of 33.8 ºC.

Figure 2-2 shows the total monthly rainfall for the period 2000 to July 2019 and also presents a rainfall residual mass (RRM) curve for the data. The RRM is calculated by subtracting the long-term average monthly rainfall from the actual monthly rainfall, to provide a monthly "departure" from average conditions. If the monthly rainfall is above average, the resulting rainfall departure number is positive, whereas if the rainfall is below average, the number is negative. A number of below-average rainfall months will result in a falling RRM curve, while a number of above average rainfall months will result in a rising RRM curve. The RRM curve is used extensively in groundwater investigations due to the strong correlation in many locations between the RRM and groundwater level trends. The RRM curve shows a downward trend from 2000 to 2007, an upward trend from 2008 to 2013 and a relatively stable trend from 2013 to present. The downward trend from 2013 to present indicates a potential for falling groundwater levels over that period for shallow aquifers where rainfall recharge is the dominant factor that affects water level rise and water levels tend to fall during periods of below-average rainfall.

Table 2-1: Average Monthly Rainfall and Evaporation (SILO Data)

Month	Average Rainfall (mm)	Average Evaporation (mm)
January	109.9	229.5
February	105.7	186.5
March	76.0	184.2
April	35.8	151.3
May	33.5	117.9
June	34.7	94.2
July	27.5	101.9
August	21.4	129.6
September	23.9	164.1
October	45.7	206.9
November	63.0	220.0
December	101.1	238.1
Total	**678.2**	**2024.2**

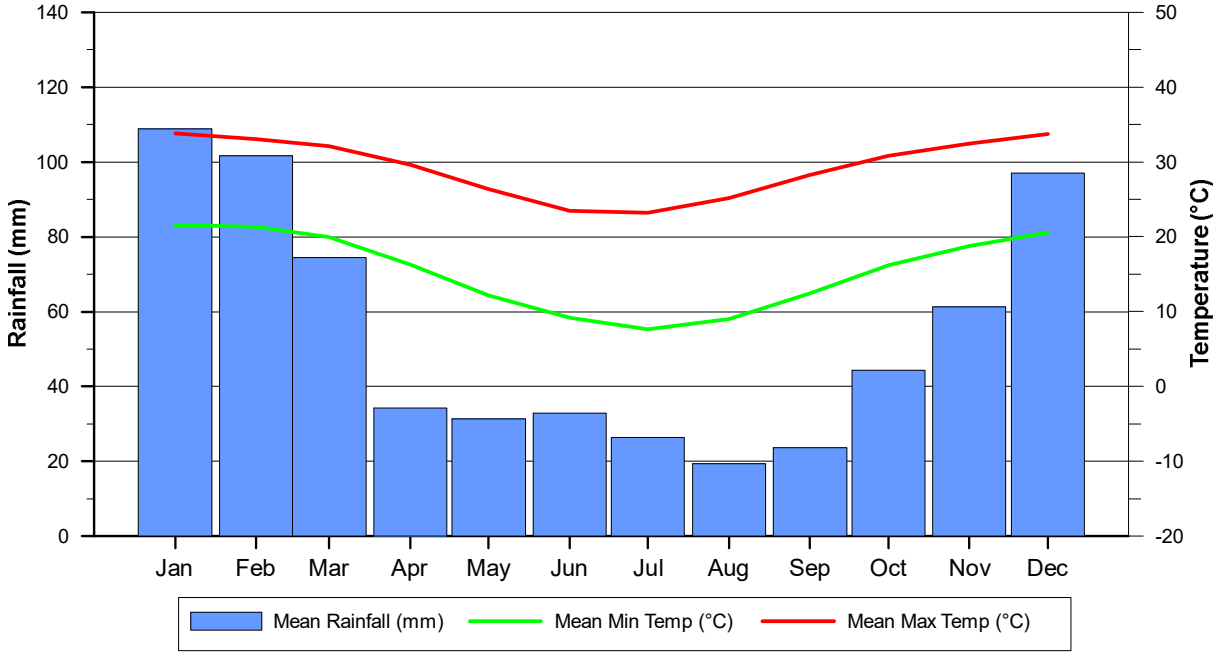

Figure 2-1: Climatograph for the Gemini Project Site

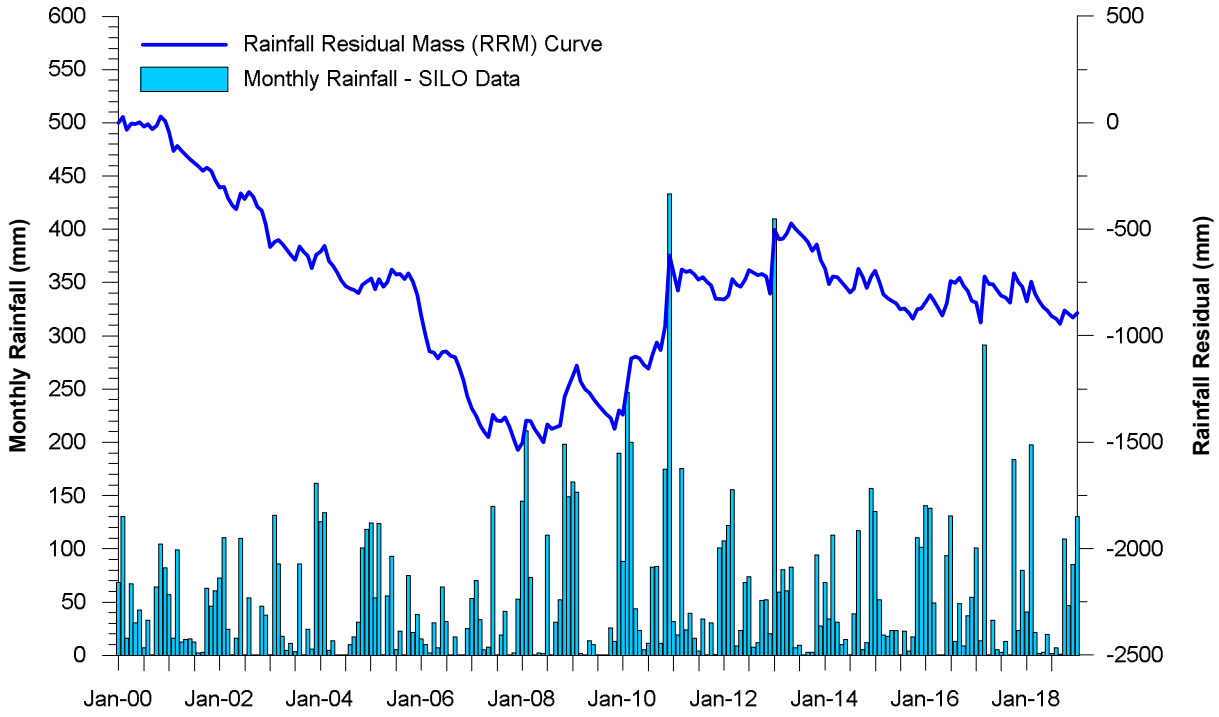

Figure 2-2: Monthly Rainfall and Rainfall Residual Mass Curve

3.0 GEOLOGY AND HYDROGEOLOGY

3.1 Stratigraphy

The Gemini coal deposit is hosted within the Permian Rangal Coal Measures and within the Yarrabee Structural Zone. Seven seams or seam groups have been identified at the Gemini Project site, which belong to either the Rangal Coal Measures or the underlying Burngrove Formation (Boyd 2019). In descending stratigraphic order the seams include the Aries, Castor, Pollux, Orion, Pisces, Virgo and Leo seams. The seams contain a number of individual plies that have identified for mining at site; the main coal seams that are encountered at site and their typical thickness are shown below in Table 3-1.

The surface geology at site is shown in Figure 3-1. It predominantly comprises sediments of the Tertiary Duaringa Formation and Quaternary alluvium associated with ephemeral creeks including Charlevue Creek and Springton Creek. At one location north of Pit C a small area of remnant basalt has been identified from drilling, measuring approximately 600 m long and 200 m wide with a thickness of approximately 20 m (JTB 2019). Bore DW7105W1 (Section 4.1) is located within the basalt and is dry.

Figure 2-2 shows the project location in relation to the underlying Bowen Basin solid geology (i.e. the surficial unconsolidated Quaternary and Tertiary units have been removed, revealing the relationship between the underlying Triassic and Permian sediments as well as the prevalence of regional-scale faults). The two mining areas (A-B Pit and C Pit) are located in areas where folding has brought the coal seams close to surface at depths that can be economically mined. Figures 3-1 and 3-2 also show the locations of east-west cross sections through each mining area and a long section through both mining areas. Data from these sections has been utilised to create cross sectional groundwater models, which are discussed below in Section 6.0.

Table 3-1: Summary of Regional and Site Stratigraphy

Geological Age	Unit	Coal Seams	Description	Typical Thickness at Site (m)
Quaternary	Alluvium		Unconsolidated soil, silt clay, sand and gravel associated with current surface drainage systems, e.g. Charlevue Creek and Springton Creek	1.5
Tertiary	Duaringa Formation		Mudstone, sandstone, conglomerate, siltstone	15 - 30
	Basalt		Minor basalt at one location north of Pit C.	20
Triassic	Rewan Group		Lithic sandstone, pebbly lithic sandstone, green to reddish brown mudstone and minor volcanilithic pebble conglomerate at base	0 - 50
Permian	Rangal Coal Measures	Aries Upper	Feldspathic and lithic sandstone, carbonaceous mudstone, siltstone, tuff and coal seams. Includes the Aries, Castor and Pollux Coal Seam, which are the target coal seam for mining at the Gemini Project	2.1
		Aries Lower		4
		Castor Upper		1.6
		Castor Lower		2
		Pollux Upper		1.9
		Pollux Lower Upper		2.9
		Pollux Lower Lower		3.5
		Orion		6.1
		Pisces Upper		1.7
		Yarrabee Tuff		0.9
		Pisces Lower		0.7
	Burngrove Formation	Virgo	Mudstone, siltstone, sandstone, coal, tuff	2.8
		Leo		4.4
	Gyranda Formation		Siltstone and shale with minor tuff and volcanilithic sandstone and rare coal	0 to 100 m+

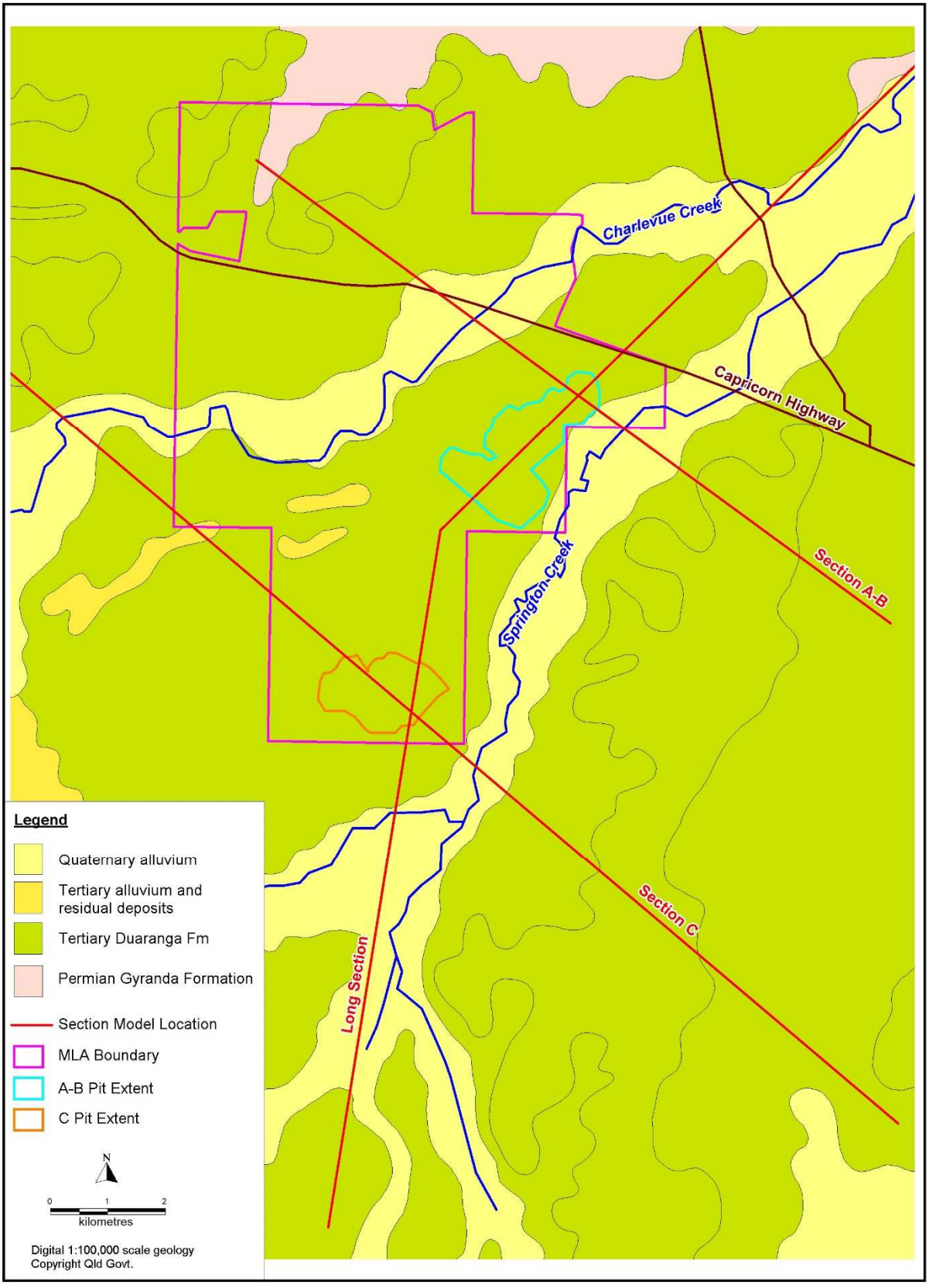

Figure 3-1: Project Location and Surface Geology (1:100,000 Scale Digital Geology)

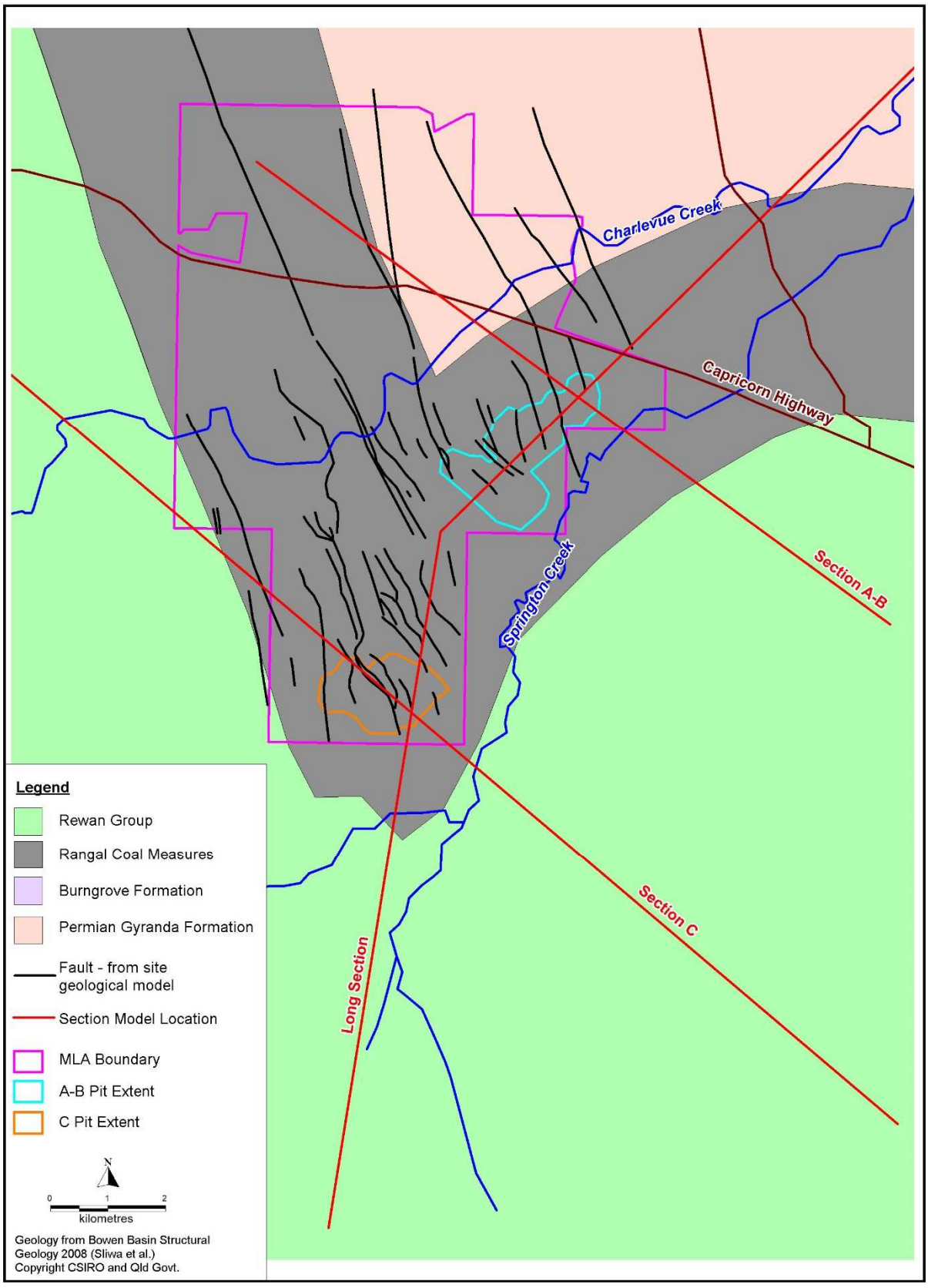

Figure 3-2: Project Location and Bowen Basin Solid Geology

3.2 Igneous Rocks and Intrusions

A minor occurrence of Tertiary basalt has been identified from geological drilling to the north of Pit C. The area of basalt is approximately 600 m long, 200 m wide and 20 m thick and has been interpreted as a localised basalt paleochannel (JTB 2019). One groundwater monitoring bore has been located within the basalt (bore DW7105W1, Section 4.1, Figures 4-1 and 4-2); the bore is 23 m deep and the basalt is dry at the bore location. The basalt flow is interpreted to be dry (as it is above the regional groundwater level) and of limited extent and is therefore not an important groundwater feature within the project area.

Extensive geological drilling across the project area has shown no other evidence of basaltic flows or intrusions (JTB 2019).

3.3 Structure

The Permian coal measures have undergone intense structural deformation, resulting in folding and faulting of the unit. Multiple reverse angle faults are present within the deposit, with displacements on some faults estimated to be in excess of 100 m (Boyd 2019). The location of mapped faults that are included in the site geological model are shown in Figure 3-2. With respect to the potential for impacts on groundwater occurrence and movement, the potential impacts are assessed to be:

- The fault zones may provide localilsed increases in hydraulic conductivity and storage that is associated with the shear zones of each fault; and,
- The faults may act as barriers to groundwater flow at locations where the faults disrupt individual coal seams, which are the main conduits for groundwater flow, especially at locations where the entire thickness of coal is displaced so that the coal seam terminates against lower-permeability interburden (the impacts of faults on groundwater are discussed further in Sections 4.6, 6.0 and 6.4).

4.0 GROUNDWATER INVESTIGATIONS AND DATA

4.1 Groundwater Monitoring Bores

The groundwater monitoring bore network at the Project site comprises 38 monitoring bores at 17 sites; bore locations are shown below in Figure 4-2, with summary details for the bores provided in Table 4-1. The monitoring bore network was designed to allow hydraulic testing as well as water level and water quality monitoring of all groundwater units encountered at site and includes:

- Two (2) bores within Quaternary alluvium;
- Ten (10) bores within Tertiary deposits (9 bores within Tertiary sediments and 1 bore (DW7105W1) in Tertiary basalt;
- Twenty-three (23) bores within Permian coal seams; and,
- Three (3) bores within the Permian overburden/interburden sediments that occur above/between the coal seams.

Bore construction logs for the monitoring bores are provided in Appendix A.

The development and utilisation of the monitoring bore network is summarised as follows:

- The network has been developed in two stages, comprising:
  - Stage 1 – installation of 11 bores at 5 sites (Sites 1 to 5 – refer Figure 4-2 and Table 4-1), with the bores installed in April 2018; and,
  - Stage 2 – Installation of a further 27 bores at 12 sites (Sites 6 to 17), with the bores drilled from May to June 2019.
- The bores at sites 1 to 5 have been monitored for water level and water quality on approximately a monthly basis since December 2018, with data available for this report from 8 sampling events between December 2018 and August 2019. Water level and water quality data is summarised below in Sections 4.2 and 4.3 respectively.
- Bores at Sites 6 to 17 were utilised for hydraulic testing (falling-head slug tests). Hydraulic tests were performed on a total of 25 bores, which provided data for all groundwater units present at site. Results from the hydraulic testing program are presented and discussed in Section 4.4.

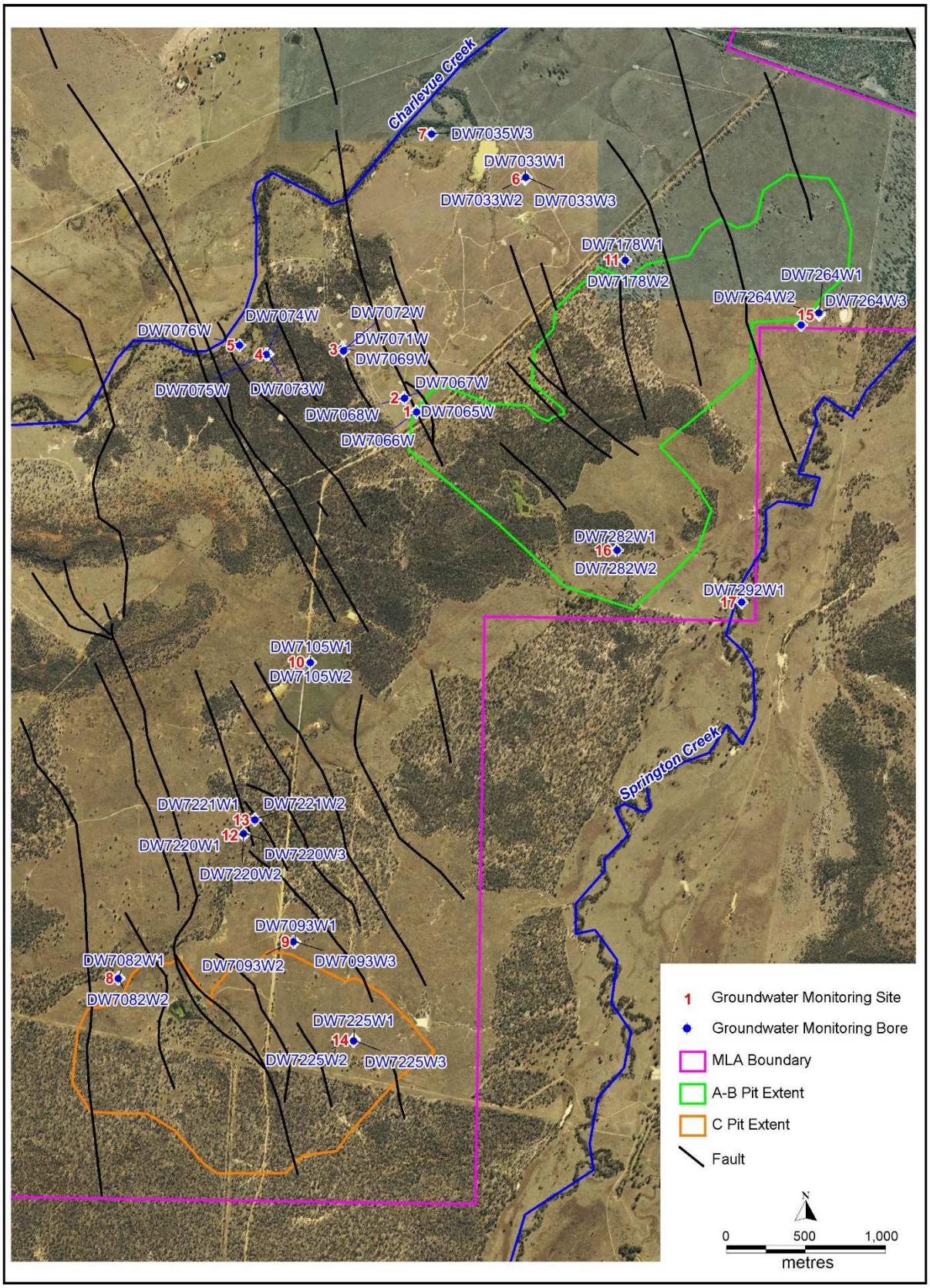

Figure 4-1: Groundwater Monitoring Bore Locations

Table 4-1: Summary Details of Groundwater Monitoring Bores

Site	Bore ID	Unit Monitored	Easting (GDA94)	Northing (GDA94)	RL (mTOC)*	Bore Depth (m)	Gravel Pack		Slotted Interval		Water Level	
							From*	To*	From*	To*	mbgl*	mAHD
1	DW7065W	Aries 3 Seam	730860	7382307	136.65	77.27	70.3	77.3	47.3	77.3	46.62	89.35
	DW7066W	Tertiary sediments	730863	7382304	137.19	17.35	10.35	17.35	Dry	17.35	Dry	-
2	DW7067W	Aries 3 Seam	730781	7382394	134.81	100.14	96.1	100.1	45.05	100.1	44.16	89.76
	DW7068W	Tertiary sediments	730785	7382391	134.94	47.5	42	47.5	45.68	47.5	44.74	89.26
3	DW7069W	Pollux Upper Seam	730397	7382699	133.46	71.38	64.4	71.4	42.73	71.4	41.84	90.73
	DW7071W	Aries 3 Seam	730394	7382703	133.22	31.59	27.6	31.6	Dry	31.6	Dry	-
	DW7072W	Tertiary sediments	730403	7382687	133.14	14.01	10	14	Dry	14	Dry	-
4	DW7073W	Castor/ Pollux Seams	729926	7382666	123.04	82.1	78.1	82.1	32.71	82.1	31.76	90.33
	DW7074W	Castor Upper Seams	729922	7382666	122.94	55.78	53.3	55.8	32.72	55.8	31.82	90.22
	DW7075W	Tertiary sediments	729918	7382666	122.83	14.03	10	14	Dry	14	Dry	
5	DW7076W	Quaternary Alluvium	729750	7382723	120.82	12	8	12	9.78	12	8.77	111.04
6	DW7033W1	Tertiary	731543	7383768	125.44	45.23	38	44.99	30.98	44.99	29.94	94.46
	DW7033W2	Orion 5 Seam	731546	7383773	125.46	74.77	72	74.5	30.02	74.5	29.01	95.44
	DW7033W3	Interburden	731548	7383777	125.47	81	78.5	81	29.97	81	28.93	95.50
7	DW7035W3	Orion 1 Seam	730957	7384050	117.73	48.47	45.9	48.44	22.81	48.44	21.75	94.92
8	DW7082W1	Castor Lower Seam	728989	7378746	136.34	40.58	38.1	40.64	17.99	40.64	16.91	118.35
	DW7082W2	Pollux Upper Seam	728986	7378742	136.32	59.17	57.6	59.17	18.03	59.17	17.04	118.29
9	DW7093W1	Pollux Lower Upper Seam	730096	7378974	140.14	87.3	84.5	87.3	29.58	87.3	28.44	110.56
	DW7093W2	Interburden	730092	7378973	140.14	99.2	97.5	99.2	29.54	99.2	28.45	110.60
	DW7093W3	Pollux Lower Lower Seam	730088	7378974	140.17	123.25	120.7	123.25	29.51	123.25	28.46	110.66
10	DW7105W1	Tertiary Basalt	730192	7380733	129.62	23.04	19	23.04	Dry	23.04	Dry	-
	DW7105W2	Pollux Lower Upper Seam	730193	7380729	129.72	69.25	61.7	64.2	32.2	64.2	31.18	97.52
11	DW7178W1	Tertiary	732174	7383260	129.62	51.15	43	48.5	38.68	48.5	37.71	90.94
	DW7178W2	Pollux Lower Upper Seam	732174	7383256	129.66	58.69	54.4	58.4	39.47	58.4	38.45	90.19
12	DW7220W1	Tertiary	729775	7379648	129.72	26.5	22.5	26.5	16.42	26.5	15.38	113.30
	DW7220W2	Castor Seam	729775	7379651	129.62	38.4	34.4	38.4	20.23	38.4	19.25	109.39
	DW7220W3	Pollux Lower Upper Seam	729774	7379655	129.67	75.08	72.5	75.04	20.03	75.04	19.04	109.64
13	DW7221W1	Aries 3 Seam	729846	7379745	130.34	50.43	46.4	50.43	21.52	50.43	20.50	108.82
	DW7221W2	Castor Seam	729845	7379742	130.32	72.36	69.8	72.36	21.57	72.36	20.50	108.75
14	DW7225W1	Tertiary	730467	7378359	141.70	37	30	37	33.43	37	32.37	108.27
	DW7225W2	Aries 3 Seam	730466	7378355	141.76	78.9	74.2	78.9	33.17	78.9	32.10	108.59
	DW7225W3	Castor Seam	730465	7378351	141.74	112.8	107	112.8	32.64	112.8	31.60	109.10
15	DW7264W1	Tertiary	733392	7382915	113.16	14	11.5	14	Dry	14	Dry	-
	DW7264W2	Aries 1 Seam	733391	7382921	113.22	104.21	101.7	104.21	22.57	104.21	21.59	90.65
	DW7264W3	Aries 3 Seam	733391	7382925	113.24	136.7	134.2	136.7	22.58	136.7	21.58	90.66
16	DW7282W1	Overburden	732119	7381433	116.84	43.03	36	43	27.25	43	26.25	89.59
	DW7282W2	Aries 3 Seam	732123	7381433	116.82	89.91	87.4	89.91	27.31	89.91	26.32	89.51
17	DW7292W1	Quaternary Alluvium	732905	7381108	114.41	15	11	15	12.02	15	11.19	102.39

* RL (mTOC) = elevation in mAHD of the top of bore casing; mbgl = metres below ground level; gravel pack and slotted interval from/to = from/to mbgl

4.2 Groundwater Levels

Available groundwater level data from the site groundwater monitoring bores is summarised as follows:

- For bores at sites 1 to 5 (refer Table 4-1), data is available to date for 9 sampling events between December 2018 and August 2019;
- For bore DW7076W, which is constructed within Quaternary alluvium adjacent to Charlevue Creek (Figure 4-2), a data logger has been fitted to the bore that records data at 3-hourly intervals. A barometric logger is also installed at the site to allow barometric correction of the data;
- For bores at sites 6 to 17, which were drilled in May/June 2019, water level data is available from field testing that was undertaken in July/August 2019.

Table 4-1 provides the most recent water level data (July/August 2019) for all monitoring sites and is summarised as follows:

- Six of the monitoring bores are dry; five of these bores are constructed within Tertiary units at depths of between 14 and 23 m and one bore is constructed with the Aries seam at a depth of 31.6 m;
- Available data for bores within the Tertiary sediments are shown below in Figure 4-2, which is summarised as follows:
    - Data shown in Figure 4-2 includes contours for RL base of Tertiary (mAHD), bore ID, water level (mAHD) and base of bore (mAHD);
    - At a number of sites where the bore is dry, the bore has not been constructed to the full depth of Tertiary sediments. These sites include DW7075W, DW7072W, DW7066W;
    - Two sites that are dry (DW7105W1 and DW7264W1) have been drilled to base of Tertiary, indicating that the Tertiary is dry at these locations. Bore DW7105W1 is constructed within the small area of remnant basalt north of C Pit that has been identified from geological drilling (section 3.1); the bore is 23 m deep and is dry;
    - There is a significant reduction in the level of the base of Tertiary to the west and north-west of AB Pit, where the level of base of Tertiary reduces from approximately 100 mAHD to 70-80 mAHD. The bores within the lower elevation area of base of Tertiary tend to record water levels in the order of 90 to 95 mAHD, whereas the bores in the range of 105 to 113 mAHD; and,
    - The presence of dry bores within the Tertiary, as well as the variation in water level between the topographically elevated base of Tertiary and topographically lower base of Tertiary, suggest that a continuous water surface does not exist in the Tertiary sediments and that the elevation of the base of Tertiary will be a control on the presence of groundwater within the sediments. From review of available data it is assessed that it is probable that the Tertiary sediments are dry above 120 mAHD and likely dry above 110 mAHD (refer Figure 4-2).
- Available data for bores within the coal seams is also shown below in Figure 4-2. In summary:
    - From the data shown in Table 4-1 it is evident that, where multiple coal seam bores exist at the one location, the water level (as mAHD) is almost identical. This suggests that there is no significant trend for upward or downward movement of groundwater between the coal seams at this location;
    - Figure 4-2 also shows groundwater level contours for the coal measures; these indicate a trend for groundwater movement within the coal seams from the southwest to the northeast, and also from the northwest to the southeast, towards a depression that is centred on the area where the AB Pit is proposed to be developed.

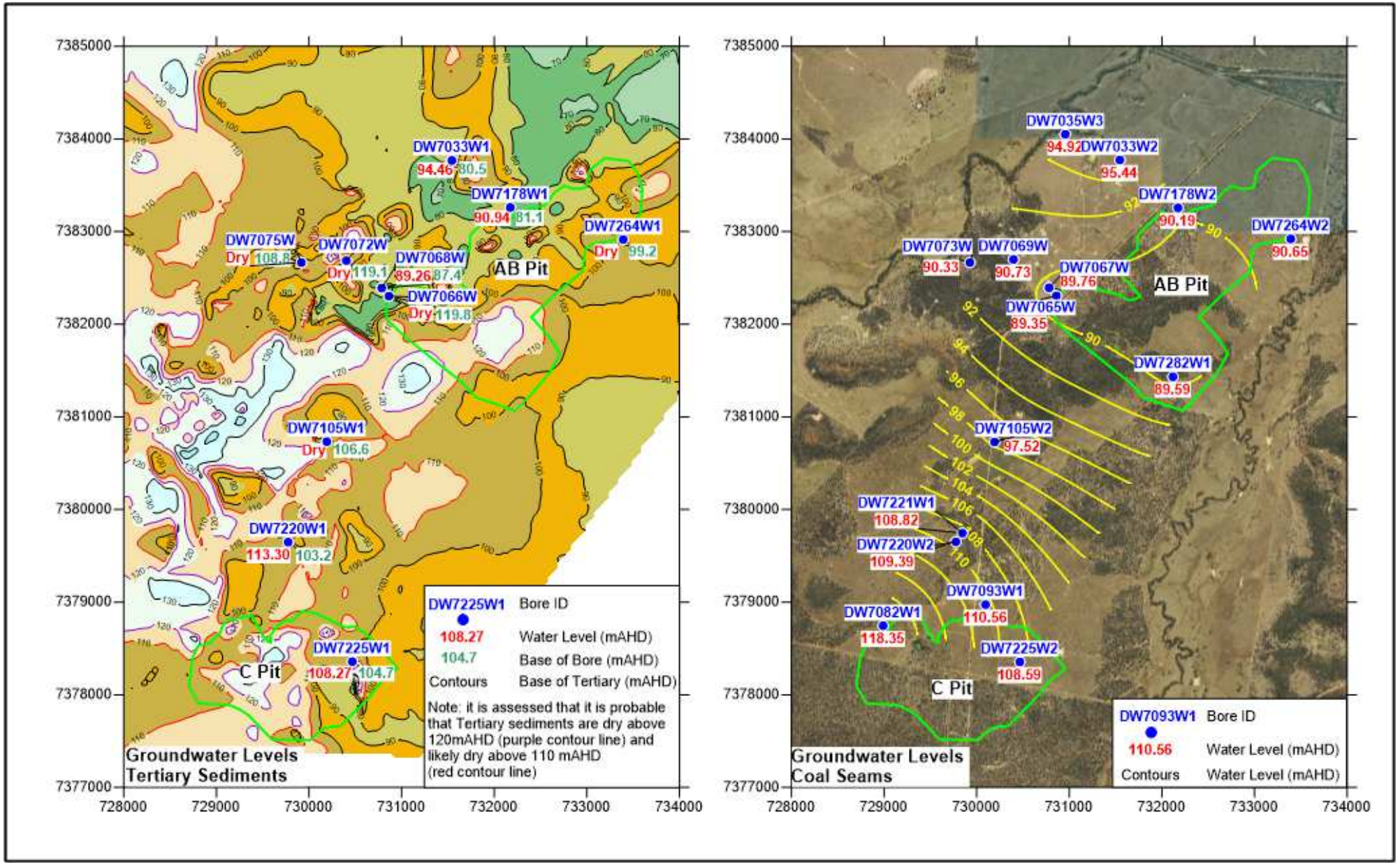

Figure 4-2: Water Level Data for Coal Seam and Tertiary Groundwater Units

For bores at Sites 1 to 5, where water level data is available from December 2018 to August 2019, the data is plotted on bore hydrographs. These are presented below and are summarised as follows:

- The bores shown on the plots below are located to the west of the AB Pit (Figure 4-2);
- When presented as water elevation data (i.e. as water level in mAHD) the data plots within a relatively tight range between approximately 88 to 90 mAHD;
- When presented as depth to water (m below ground level - mbgl), the range is from approximately 33 to 47 mbgl. This serves to highlight that the variability in the depth to groundwater is mainly related to the variation in surface topography, with the groundwater elevation in a particular area being relatively consistent; and,
- Figure 4-2 shows the location of bore DW7073W to the west of the AB Pit. This site also includes bore DW7074W, which is not shown in Figure 4-2. This is because only one coal seam bore was selected for generation of the water level contours shown in Figure 4-2, due to the similarity between the water levels within different coal seams at each site (refer water level data in Table 4-1). This relationship is highlighted in the water level data for bores DW7073W and DW7074W in the depth to water plot below; for these bores it can be seen that the water level is the same (within 0.1 m) for each monitoring event.

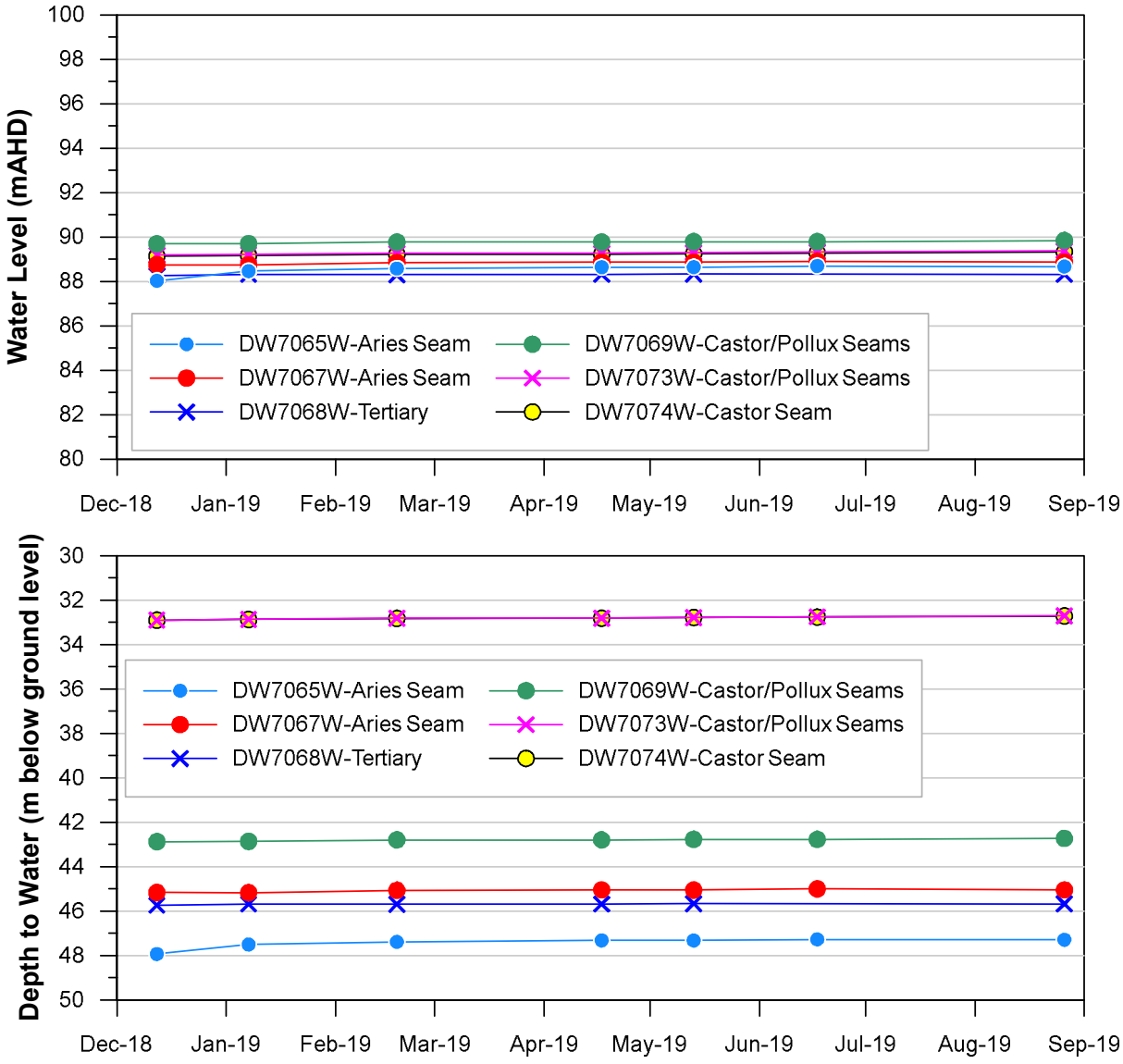

Figure 4-3: Water Level as Elevation (mAHD-top plot) and Depth to Water (mbgl-bottom plot)

Bore DW7076W (refer Figure 4-1 for bore location) is screened within Quaternary alluvium adjacent to Charlevue Creek. The bore has been fitted with a data logger that records water level at 3-hourly intervals, to allow the relationship between creek flow and water level to be established over time. To date the water level has been relatively stable, displaying a slightly downward water level tend between 9 and 10 mbgl. It is uncertain at this stage whether the reduction in water level is related to the ongoing removal of groundwater from the bore during sampling events (with the reduction in water level following sampling being evident in the bore hydrograph. Further data will be required at this site to establish the long-term water level trend.

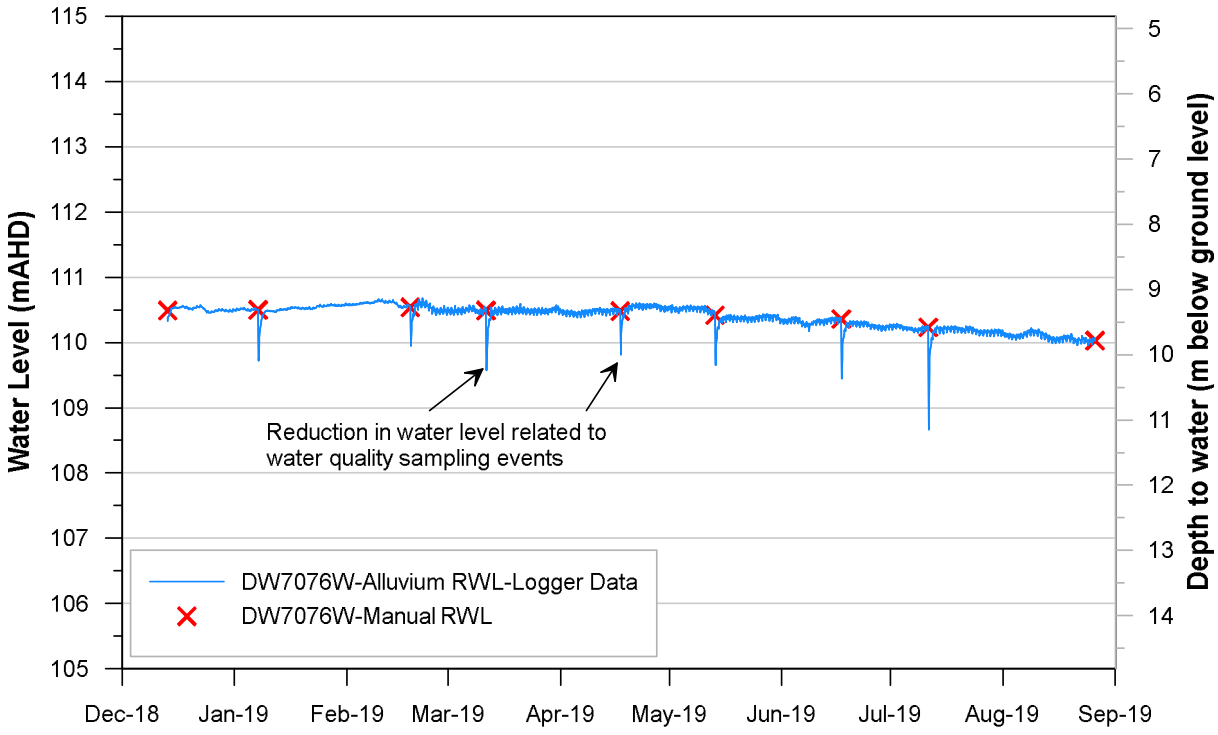

Figure 4-4: Water Level Data for Quaternary Alluvium Bore DW7076W

4.3 Groundwater Quality

Groundwater quality data is available for 8 sampling events that have occurred at approximately monthly intervals between December 2018 and August 2019. Available data includes:

- pH (field and laboratory data);
- Electrical Conductivity (EC – field and laboratory data);
- Total Dissolved Solids (TDS);
- Major ions (sodium, calcium, magnesium, potassium, chloride, sulphate, alkalinity); and,
- Total and dissolved metals/metalloids (aluminium, arsenic, barium, beryllium, boron, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, uranium, vanadium, zinc).

Available data is included as summary tables in Appendix B. Observations from review of the data area summarised as follows:

- pH (Field)
  - Quaternary alluvium - the pH ranges from 7.05 to 7.49, with a mean of 7.30 and median of 7.33;

- Tertiary sediments - the pH ranges from 6.78 to 7.06, with a mean of 6.93 and median of 6.94; and,
- Coal seams - the pH ranges from 6.21 to 6.84, with a mean of 6.44 and median of 6.42.

- Electrical Conductivity (EC – lab)
  - Quaternary alluvium - the EC at bore DW7076W (Charlevue Creek alluvium) ranges from 15,200 µS/cm to 16,600 µS/cm, with a mean of 15,788 µS/cm and median of 15,700 µS/cm (8 samples). A single field value from bore DW7292W1 (Springton Creek alluvium) recorded an EC of 5,948 µS/cm;
  - Tertiary sediments - the EC ranges from 20,200 µS/cm to 21,900 µS/cm, with a mean of 20,843 µS/cm and median of 20,800 µS/cm; and,
  - Coal seams - the EC ranges from 22,100 µS/cm to 28,500 µS/cm, with a mean of 25,693 µS/cm and median of 25,600 µS/cm.
- Sulphate (SO_4). Due to the high salinity of the groundwater, samples are also relatively high in sulphate, especially for the coal seams, with data summarised as:
  - Quaternary alluvium - the sulphate concentration ranges from 204 mg/L to 249 mg/L, with a mean of 217 mg/L and median of 212 mg/L;
  - Tertiary sediments - the sulphate concentration ranges from 291 mg/L to 635 mg/L, with a mean of 367 mg/L and median of 334 mg/L; and,
  - Coal seams - the sulphate concentration ranges from 341 mg/L to 841 mg/L, with a mean of 622 mg/L and median of 642 mg/L.
- Dissolved metal/metalloid data has been analysed with reference to the ANZECC 2000 95% freshwater ecosystem protection trigger values for parameters where guideline values exist; these include aluminium, arsenic, boron, cadmium, copper, lead, mercury, nickel, selenium, silver and zinc. Observations of note include:
  - All groundwater samples are above the guideline limit for boron of 0.37 mg/L, with data summarised as:
    - Quaternary alluvium – the boron concentration ranges from 0.56 to 4.56 mg/L, with mean of 3.50 mg/L and median of 3.81 mg/L;
    - Tertiary sediments – the boron concentration ranges from 1.14 to 1.52 mg/L, with mean of 1.28 mg/L and median of 1.26 mg/L; and,
    - Coal seams - the boron concentration ranges from 0.88 to 1.49 mg/L, with mean of 1.23 mg/L and median of 1.25 mg/L.
  - The majority of groundwater samples are above the guideline limit for copper of 0.0014 mg/L, with data summarised as:
    - Quaternary alluvium – the copper concentration ranges from 0.002 to 0.023 mg/L, with mean of 0.013 mg/L and median of 0.011 mg/L (9 samples, all samples >LOR);
    - Tertiary sediments – the copper concentration ranges from 0.001 to 0.014 mg/L, with mean of 0.004 mg/L and median of 0.003 mg/L (7 samples, 4 samples >LOR); and,
    - Coal seams - the copper concentration ranges from 0.001 to 0.081 mg/L, with mean of 0.011 mg/L and median of 0.003 mg/L (45 samples, 25 samples >LOR).
  - The majority of groundwater samples are above the guideline limit for zinc of 0.008 mg/L, with data summarised as:

- Quaternary alluvium – the zinc concentration ranges from 0.007 to 0.028 mg/L, with mean of 0.014 mg/L and median of 0.011 mg/L (9 samples, 7 samples >LOR);
- Tertiary sediments – the zinc concentration ranges from 0.017 to 0.096 mg/L, with mean of 0.049 mg/L and median of 0.035 mg/L (7 samples, all >LOR); and,
- Coal seams - the zinc concentration ranges from 0.025 to 0.21 mg/L, with mean of 0.086 mg/L and median of 0.075 mg/L (45 samples, all >LOR).

o A number of samples exceed the guideline values for aluminium, arsenic, lead and nickel.

The samples collected to date represent background water quality for the site. It can therefore be summarised that:

- Groundwater at site records very high EC for all groundwater units (Quaternary alluvium, Tertiary sediments and Permian coal measures). It is noted that the ANZECC 2000 livestock limit for beef cattle is 4,000 mg/L; this corresponds to an EC of approximately 6,000 µS/cm at a conversion factor of EC (µS/cm) x 0.67 = TDS (mg/L) (ANZECC 2000). It is therefore concluded, based on EC data, that groundwater at site is unsuited to stock watering; and,
- Groundwater at site is above the ANZECC 2000 freshwater ecosystem protection trigger value (95% species protection) for boron (all samples), copper and zinc (majority of samples) as well as aluminium, arsenic, lead and nickel (a number of samples for each analyte).

4.4 Hydraulic Conductivity data from Monitoring Bores

Falling head (slug) tests were undertaken on 25 monitoring bores in order to obtain site-specific hydraulic conductivity (K) data from all groundwater units that are encountered at site. The results for each bore are shown below in Table 4-2. Summary data for each groundwater unit are discussed further below and are provided in Table 4-3 and the slug test analysis sheets are included in Appendix C.

Table 4-2: Hydraulic Conductivity and Air Lift Yield Data for Monitoring Bores

Hole	Groundwater Unit	Centre of Screened Interval (mbgl)	SWL (mBTOC)	Hydraulic Conductivity (K) (m/day)	Air Lift Yield (L/s)*
DW7292W1	Alluvium	13.5	12.02	0.097	
DW7220W1	Tertiary	25.0	16.42	0.045	0.010
DW7225W1	Tertiary	34.0	33.43	0.444	0.010
DW7282W1	Tertiary	40.0	27.25	0.027	0.010
DW7033W1	Tertiary	42.0	30.98	0.703	2.250
DW7178W1	Tertiary	46.3	38.68	3.805	0.460
DW7220W2	Castor	35.4	20.23	0.012	0.010
DW7082W1	Castor Lower	39.8	17.99	5.387	2.180
DW7035W3	Orion 1	47.7	22.81	1.593	0.010
DW7221W1	AR3	48.9	21.52	0.286	0.010
DW7178W2	PLU2	56.9	39.47	0.532	0.330
DW7082W2	Pollux Upper	58.4	18.03	1.855	1.840
DW7105W2	PLU1	63.5	32.20	0.066	0.010
DW7221W2	Castor	71.6	21.57	0.243	1.530
DW7033W2	Orion 5	73.8	30.02	0.061	2.180
DW7220W3	PLU1	74.3	20.03	0.293	1.530
DW7225W2	AR3	77.4	33.17	2.141	7.730
DW7093W1	Pollux Upper 2	86.6	29.58	0.022	0.610
DW7282W2	AR3	89.2	27.31	0.245	0.220
DW7264W2	AR1	103.5	22.57	0.009	0.220
DW7225W3	Castor	111.3	32.64	0.002	
DW7093W3	PLL2	122.5	29.51	0.039	0.330
DW7264W3	AR3	136.0	22.58	0.011	0.220
DW7033W3	Interburden	80.3	29.97	0.002	2.250
DW7093W2	Interburden	98.5	29.54	0.001**	

* Air Lift Yield data was obtained from the base of bore prior to bore construction and therefore represents the yield of the entire open interval

** Data could not be analysed due to lack of recovery over test period – K set at low value of 0.001 m/day

The data was also reviewed in association with data from air-lift yield testing of the groundwater monitoring bores, which was undertaken at the completion of drilling (i.e. at the base of the hole) and prior to bore construction. From review of the combined dataset of hydraulic conductivity data and air-lift yield data, and with reference to information contained in Table 4-2, Table 4-3 and Figure 4-2, the following observations are made:

- A total of 17 slug tests were performed on bores that are screened within the coal seams. From review of the data it is evident that the K decreases with depth and that the difference becomes apparent when comparing data for coal seam bores that are screened at a depth of less than 80 metres below ground level (mbgl) to data for bores that are screened at a depth greater than 80 mbgl;

- Table 4-3 contains summary statistics (minimum value, maximum value and geometric mean) for the K of the coal seams, which is summarised as follows:
  - For data for all coal seams (17 data points), the K range is from 0.002 to 5.4 m/day, with a geometric mean of 0.13 m/day
  - For coal seam bores that are screened above 80 mbgl (11 data points) the K range is from 0.012 to 5.4 m/day, with a geometric mean of 0.37 m/day
  - For coal seam bores that are screened below 80 mbgl (6 data points) the K range is from 0.002 to 0.24 m/day, with a geometric mean of 0.02 m/day;
- The relationship between hydraulic conductivity and depth is shown graphically in Figure 4-2. Of particular interest is the data for the coal seam bores, where the trend for the lower K with depth is shown via the trend line and the 95% confidence interval that has been applied to the data (curves have been automatically fit within the software program Grapher).

Table 4-3: Summary of Hydraulic Conductivity and Air-Lift Yield Data per Groundwater Unit

Groundwater Unit	No. of Tests	Hydraulic Conductivity (m/day)			Average Air-Lift Yield (L/s)
		Min	Max	Geometric Mean	
Quaternary Alluvium	1	0.097		-	-
Tertiary	5	0.027	3.805	0.27	0.548
Permian Coal Seams	17	0.002	5.387	0.13	1.185
Coal Seams <80 mbgl	11	0.012	5.387	0.37	1.578
Coal Seams >80 mbgl	6	0.002	0.245	0.02	0.320
Permian Interburden	2	0.001	0.002	-	-

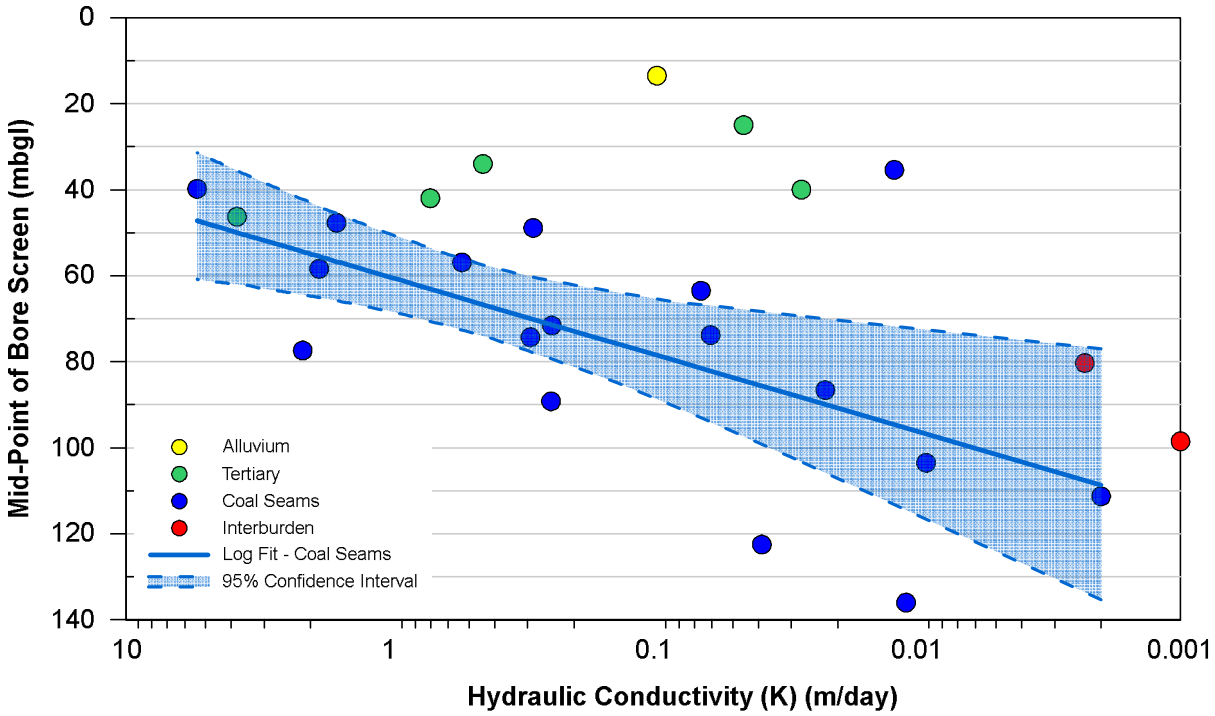

Figure 4-5: Relationship between Hydraulic Conductivity and Depth

4.5 Use of Groundwater Quality Data for Estimating Groundwater Recharge

Groundwater data from site has been utilised to provide an estimate of groundwater recharge based on the chloride mass balance (CMB) method, which utilises the concentration of chloride in rainfall and the concentration of chloride in groundwater to provide an estimate of the net recharge rate to groundwater. The CMB equation is given as:

$$R = \frac{PCp}{Cg}$$

Where:

R = Recharge (mm/year).

P = Rainfall (mm/year).

Cp = Chloride concentration in rainfall (mg/L).

Cg = Chloride concentration in groundwater (mg/L).

Utilising the above formula, the recharge rates for each groundwater unit were calculated using the following input data:

- Mean annual rainfall for the Gemini project site of 678 mm (from SILO data).
- Mean chloride concentration in rainfall for the Gemini project site of 4.9 mg/L (CSIRO 2014[1]).
- Mean chloride concentration of groundwater (refer Appendix B) of:
  - 4,088 mg/L for the alluvium;
  - 7,440 mg/L for Tertiary sediments; and,
  - 9,081 mg/L for the Permian coal seams.

The calculated recharge rates to groundwater are very low, being less than 1 mm of rainfall recharge for each groundwater unit at site and corresponds to approximately 0.05 to 0.12% of average annual rainfall reporting as recharge to the groundwater units.

While the calculated recharge rates are assessed to be low, the low recharge rates are consistent with the high salinity of the groundwater, which is observed for even the shallow alluvial units at site.

Table 4-4: Calculated Recharge via CMB Method

Parameter	Description	Groundwater Unit		
		Alluvium	Tertiary	Coal Seams
Cg	Chloride concentration in groundwater (mg/L)	4088	7440	9081
Cp	mg/L chloride in rainfall	4.9	4.9	4.9
P	Annual average rainfall (mm)	678	678	678
R	Annual average recharge (mm)	0.78	0.43	0.35
	Recharge as % of average annual rainfall	0.12	0.07	0.05

[1] CSIRO 2014 - Australian Chloride Deposition Rate https://doi.org/10.4225/08/545BEE54CD4FC

4.6 Summary of Observations from Site Data

The main observations from review of site data are as follows:

- Groundwater occurs within three main groundwater units at site, including:
  - Quaternary alluvium associated with Charlevue Creek and Springton Creek;
  - Tertiary sediments of the Duaringa Formation; and,
  - The Permian coal measures, where groundwater occurs preferentially within the coal seams.
- The site is heavily faulted and the faults may act to influence groundwater occurrence and movement as follows:
  - Shear zones associated with faulting may act as a store of water and as locally higher hydraulic conductivity zones. As discussed below, recharge to the groundwater system is assessed to be low; therefore the faults may provide initial relatively high inflow rates to the workings (in the order of several L/s), but the total storage within the faults is anticipated to be relatively low, with the initial rates of inflow not able to be sustained in the long-term; and,
  - Where the faults completely disrupt the coal seams, especially for cases where the coal seam terminates against lower-hydraulic conductivity interburden, the faults will act to disrupt groundwater flow.
- Available hydraulic conductivity and air-lift yield data indicates that there is notable reduction in hydraulic conductivity and bore yield for bores that are deeper than 80 mbgl compared to bores that are shallower than 80 mbgl.
- Groundwater level data at site are summarised as:
  - The water level within the alluvium ranges from 8.77 m to 11.19 m below ground level for bores adjacent to the creek channels;
  - The water level with the Tertiary sediments ranges from dry (5 bores, ranging in depth from 14 to 23 m) to 15.38-44.74 mbgl (where water is present). The presence of water within the Tertiary sediments is related to the RL of the base of Tertiary and from review of available data it is assessed that it is probable that the Tertiary sediments are dry above 120 mAHD and likely dry above 110 mAHD; and,
  - The water level in the coal measures ranges from 16.91 to 46.62 mbgl for bore depths of between 38.4 and 136.7 m, with one bore dry at a depth of 31.59 m.
- Groundwater quality data is summarised as:
  - All groundwater units at site record high EC groundwater, as follows:
    - Quaternary alluvium – bore DWDW7076W (Charlevue Creek alluvium) records an EC range from 15,200 µS/cm to 16,600 µS/cm (8 samples). A single field value for bore DW7292W (Springton Creek alluvium) records an EC of 5,948 µS/cm;
    - Tertiary sediments - the EC ranges from 20,200 µS/cm to 21,200 µS/cm; and,
    - Coal seams - the EC ranges from 22,100 µS/cm to 28,500 µS/cm.
  - Groundwater at site is above the ANZECC 2000 freshwater ecosystem protection trigger value (95% species protection) for boron (all samples), copper and zinc (majority of samples) as well as aluminium, arsenic, lead and nickel (a number of samples for each analyte).
  - All groundwater samples collected to date are assessed to represent the background water quality for the site.

- The recharge rate to the groundwater units at site, which has been calculated via the chloride mass balance method, indicates an extremely low recharge rate of less than 1 mm/year for each groundwater unit. The low rate of calculated recharge is consistent with the observation of highly saline groundwater at site, which is present for even the shallow alluvial units.
- The observation of a low recharge rate for groundwater suggests that, even though relatively high rates of groundwater inflow may be observed from faults/shear zones as mining progresses, the inflow rates are likely to be of short duration due to the relatively low volume that can be stored within fractures/faults and the very low rates of recharge observed at site (i.e. once the fault storage is depleted the faults are unlikely to be recharged).
- Because the faults may act as conduits for groundwater movement, the control of surface water around the site will be of particular importance (i.e. water that ponds at surface may recharge the underlying sediments and report as seepage to the pits via movement along faults/fractures. This type of flow would represent infiltrated surface water rather than groundwater.

4.7 Regional Groundwater Use

Data from DNRM groundwater database within a distance of 10 km from the EPC boundary is shown below in Figure 4-6 and summary data is provided in Table 4-4. With reference to the information in Table 4-4 and Figure 4-6 the following observations are made:

- There are 48 registered bores within 10km of EPC881 that are listed as being either existing or abandoned by useable.
- The majority of bores are screened within Tertiary units (26 bores) or Permian coal measures (15 bores).
- The right-hand plot in Figure 4-6 shows the available data classed according to EC range, being:
  - Bores that record an EC <1000 µS/cm. This includes four bores in Tertiary sediments to the east or south of the project area;
  - Bores that record an EC between 1,000 and 6,000 µS/cm. A limit of 6,000 µS/cm was assessed as this EC equates to 4,000 mg/L[2], which is the ANZECC 2000 livestock drinking limit for beef cattle (assessed to the most likely stock use for the area); and,
  - Bores that record an EC >6,000 µS/cm (assessed to be of limited or no use for stock watering).
- The majority of Tertiary bores outside the tenement area record an EC of < 6,000 µS/cm, whereas the majority of bores within or close to the tenement area record and EC in excess of 6,000 µS/cm (from Table 4-4 it is noted that the EC of groundwater within the Tertiary Duaringa Formation is often in excess of 10,000 µS/cm and at some sites in excess of 20,000 µS/cm; this observation is consistent with water quality data from site).

Data from private groundwater bores is discussed further in Sections 7.1 and 7.2.1.

2

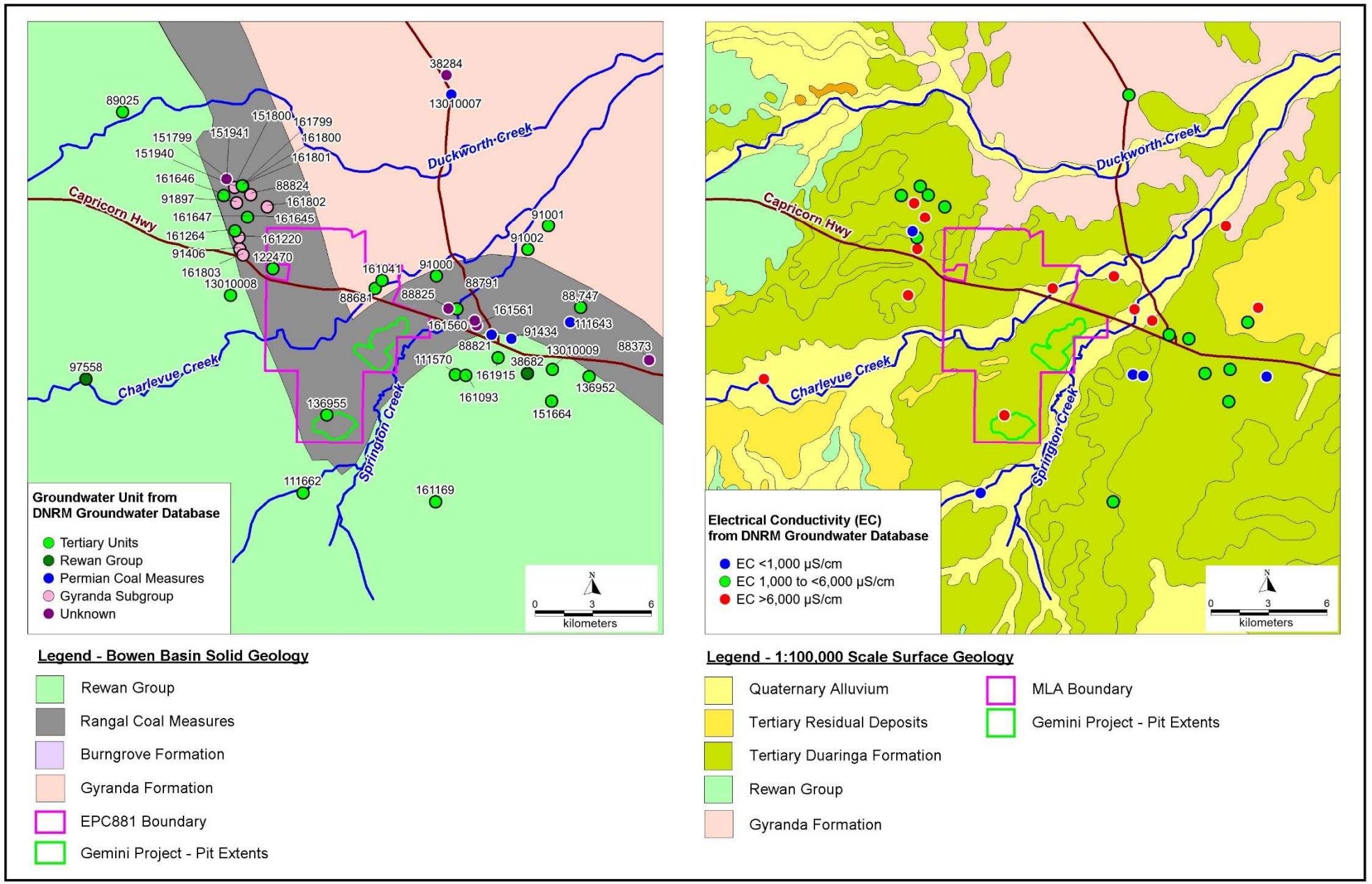

Figure 4-6: Aquifer Data and Groundwater EC Data from DNRM Groundwater Database

Table 4-5: Summary Data from DNRM Groundwater Database for Bores within 10km of EPC Boundary

RN	EASTING GD94	NORTHING GDA94	FACILITY_STATUS	Aquifer	DRILLED_DATE	EC (µS/cm)	Water Quality Description	YIELD (L/s)	SWL (mbgl)	Original Bore Name
38284	735584	7396485	Existing	Unknown						SANDY CREEK BORE
38682	739791	7381024	Existing	DUARINGA FORMATION	31-Oct-72	2370		0.19	-5.3	
88373	746081	7381702	Existing	Unknown	01-Jan-15					GOOWARRA WELL
88681	731897	7385429	Existing	DUARINGA FORMATION	28-Nov-92	10000		2.5		
88747	742541	7384432	Existing	DUARINGA FORMATION	15-Feb-93	10360		1.1		
88791	736137	7384353	Existing	DUARINGA FORMATION	06-Apr-93	19200		0.78	-20	NEW BORE
88821	737932	7383029	Existing	RANGAL COAL MEASURES	03-Apr-93	4510		0.63	-8	FITZGERALDS PLACE
88824	725449	7390299	Existing	GYRANDA SUBGROUP	05-Apr-93	3800		0.78	-15	BORE 3
88825	735685	7384385	Existing	Unknown						WINDMILL
89025	718817	7394577	Existing	BASALT	01-Jan-64			0.4		
91000	735078	7386067	Abandoned but Usable	DUARINGA FORMATION	07-Apr-93	14660		0.75	-20	MACKENZIE OLO
91001	740865	7388678	Abandoned but Usable	DUARINGA FORMATION	18-Apr-93	42000		1.5	-24	MACKENZIE OLO
91002	739796	7387438	Abandoned but Usable	DUARINGA FORMATION	19-Apr-93		SALTY	2.1		MACKENZIE OLO
91406	724894	7387470	Existing	GYRANDA SUBGROUP	04-Aug-94	9240		0.32	-30.5	
91434	738947	7382824	Existing	RANGAL COAL MEASURES	16-Aug-94	1080		2.14		DINGO RACECOURSE
91897	724724	7389881	Existing	GYRANDA SUBGROUP	31-Dec-99	15330		0.65		NAUGHTON (OLO)
97558	716925	7380734	Existing	REWAN GROUP	09-Jul-96	7600		0.36	-27.4	SIMON CATTLE CO
111570	736059	7380966	Existing	TERTIARY - UNDEFINED	02-Nov-01	240		1.2	-16	WARD
111643	741998	7383678	Existing	BLACKWATER GROUP - UNDIFF.	03-Oct-01	4120		4.4	-27.4	G SMITH
111662	728169	7374811	Existing	TERTIARY - UNDEFINED	29-Dec-01	750		2.5	-17	SMITH
122470	726594	7386438	Existing	TERTIARY - UNDEFINED						
136131	707571	7381259	Existing	DUARINGA FORMATION	27-Mar-06	900		1.3	-18	
136952	742978	7380858	Existing	TERTIARY - UNDEFINED	27-Jan-07	848		0.1	-17.37	
136955	729388	7378869	Existing	TERTIARY - UNDEFINED	30-Sep-08	10300		2.2	-21	
151664	741024	7379579	Existing	DUARINGA FORMATION	14-Feb-10	1250	POTABLE	0.25	-26	
151799	724194	7391110	Existing	GYRANDA SUBGROUP	22-Jan-13		POTABLE	2.1	-71	
151800	724628	7390671	Existing	BLACKWATER GROUP	23-Jan-13		POTABLE	0.31	-20	
151940	724627	7390671	Existing	GYRANDA SUBGROUP	28-Sep-13		POTABLE	0.31	-20	
151941	724194	7391113	Existing	Unknown	28-Sep-13		POTABLE	2.1	-71	
161041	732247	7385838	Existing	DUARINGA FORMATION	28-Apr-14		BRACKISH	1	-29	
161093	736592	7380908	Existing	TERTIARY MAFIC VOLCANICS	31-Aug-14	710	FRESH	0.61	-19.5	
161169	735022	7374342	Existing	TERTIARY - UNDEFINED	12-Oct-13	3300		0.25	-15	
161220	724858	7388061	Existing	BANANA FORMATION	21-Dec-14	2400		1.2	-32	
161264	724639	7388396	Existing	DUARINGA FORMATION	30-Mar-15	960		1.5	-54	
161560	737046	7383758	Existing	Unknown	28-Nov-16	28102				DINGO LANDFILL MW2
161561	737159	7383502	Existing	Unknown	29-Nov-16					DINGO LANDFILL MW1
161645	725283	7389134	Existing	DUARINGA FORMATION	06-Jul-17		BRACKISH	1	-27.64	MB01
161646	724053	7390267	Existing	DUARINGA FORMATION	07-Jul-17	2942				MB02
161647	725283	7389134	Existing	DUARINGA FORMATION	09-Jul-17	29000	BRACKISH		-36.87	MB03
161799	725034	7390748	Existing	GYRANDA SUBGROUP	16-Apr-18	4420	BRACKISH	0.4		MB04C (AQ090A)
161800	725026	7390758	Existing	GYRANDA SUBGROUP	16-Apr-18	5459	SALTY	0.6		MB04B (AQ090B)
161801	725020	7390764	Existing	DUARINGA FORMATION	16-Apr-18					AQ090C
161802	726308	7389681	Existing	GYRANDA SUBGROUP	16-Apr-18	1380	SALTY	7.5		MB06 (AQ091)
161803	725061	7387160	Existing	GYRANDA SUBGROUP	16-Apr-18		SALTY-BRACKISH	0.4		QQ092
161915	738258	7381843	Existing	DUARINGA FORMATION	10-Sep-18			1.62	-4.5	
13010007	735835	7395478	Abandoned but Usable	BLACKWATER GROUP	28-Oct-04	1534				
13010008	724410	7385071	Existing	DUARINGA FORMATION	31-Oct-04	16100				
13010009	741076	7381232	Abandoned but Usable	DUARINGA FORMATION	02-Nov-04	3690				

5.0 CONCEPTUAL GROUNDWATER MODEL

Essential elements of the conceptual model that have informed numerical modelling include:

- Quaternary alluvium is present within ephemeral water courses to the east and west of the mining area (Springton Creek and Charlevue Creek respectively);
- Tertiary deposits are present across the project area that comprise mainly sediments of the Duaringa Formation. The Tertiary sediments are variably saturated the elevation of the base of Tertiary being a control on the occurrence of water within the sediments; it is assessed that Tertiary sediment above approximately 110 mAHD are likely to be unsaturated;
- A minor area of Tertiary basalt is present to the north of Pit C; the basalt is interpreted to be dry and of limited extent and is therefore not considered as a groundwater unit at site;
- Recharge to alluvium and Tertiary sediments is via direct rainfall recharge. The rate of recharge to the alluvium and Tertiary sediments is calculated by the chloride mass balance method (Section 4.5) to be in the order of 0.4 to 0.8 mm/year (0.07 to 0.12 % of annual average recharge respectively). The low rate of recharge is consistent with the observation of elevated salinity in the shallow sediments, with an EC range for alluvial sediments from 15,200 µS/cm to 16,600 µS/cm and for Tertiary sediments from 20,200 µS/cm to 21,200 µS/cm. The high EC that is recorded for the shallow sediments (alluvium and Tertiary) is interpreted to be reflective of a low rate of groundwater recharge as well as high residence times for groundwater;
- The coal measures are heavily faulted and folded and mining occurs where folding and faulting has brought the coal seams close to surface, as shown below in Figures 6-2 to 6-6;
- The coal seams are recharged in subcrop areas where the coal seams directly underlay Tertiary and/or Quaternary sediments. The rate of recharge to the coal seams has been calculated by the CMB method (Section 4.5) to be in the order of 0.05% of average annual rainfall. The extremely high salinity of groundwater within the coal measures (range from 22,100 µS/cm to 28,500 µS/cm) supports an interpretation of a low rate of recharge and high groundwater residence times for these units;
- Within the Permian coal measures the coal seams are the primary conduits for groundwater flow. This interpretation is supported by hydraulic conductivity data from site testing, which indicates a much lower hydraulic conductivity of interburden/ overburden units relative to the hydraulic conductivity of the coal seams;
- Hydraulic conductivity data (from testing of completed monitoring bores) and air-lift yield data (from air-lift testing undertaken at the base of the bore on completion of drilling and prior to bore construction) indicates that the shallow coal seams (shallower than approximately 80 mbgl) have a higher hydraulic conductivity and are higher yielding than the coal seams below 80 mbgl;
- The relatively high rates of groundwater flow (from air-lift yield testing) for bores shallower than 80 m may be related in some cases to proximity to faults, as the hydraulic conductivity calculated for some of the coal seams (in excess of 1.5 m/day at four sites) is assessed to be greater (by approximately an order of magnitude) than the geometric mean of the coal seam data;
- However, taken together with the interpreted low rate of recharge and high groundwater salinity it is interpreted that, while the faults may locally increase hydraulic conductivity and storage within the secondary porosity of the shear zones, the faults also act to compartmentalise the groundwater system (for example by truncating the coal seams so that they terminate against lower hydraulic

conductivity interburden); this leads to high residence times for groundwater that contributes to the elevated groundwater salinity;

- The direction of groundwater flow within the coal seams is generally from southwest to northeast; and,
- It is interpreted that a continuous water surface does not exist in the Tertiary sediments and that the elevation of the base of Tertiary will be a control on the presence of groundwater within the sediments. From review of available data it is assessed that it is probable that the Tertiary sediments are dry above 120 mAHD and likely dry above 110 mAHD.

6.0 GROUNDWATER MODELLING

6.1 Choice of Numerical Model

To estimate the extent of water level impact from the proposed project, 2-dimensional seepage modelling has been undertaken using the program Seep/W. The choice of model code has been based on an assessment of the model platform that would be appropriate to the study requirements.

A number of factors are assessed when choosing the appropriate modelling platform for a particular groundwater modelling study. Factors that are relevant to the Gemini Project include:

- The ability of the model to represent the essential elements of the conceptual groundwater model. At the Gemini Project this includes the ability of the model to accurately represent the complexity of the geology including faulting of strata, which acts to compartmentalise the geological and hydrogeological units, as faulting has the potential to significantly impact groundwater occurrence and flow; and,
- The ability of the model to adequately address the requirements of the scope of work. At the Gemini Project this includes assessment of the extent of groundwater level impact from mining, assessment of the potential impact of groundwater level changes on any groundwater dependant ecosystems, and assessment of the rate of groundwater inflow to the active mining area and final voids.

Based on assessment of the model requirements, including representation of the essential elements of the conceptual groundwater model, it was concluded that 2-dimensional cross-section modelling would be appropriate for the Gemini project and on that basis the model Seep/W was selected. The use of a 2-dimensional Seep/W cross-section model was assessed to be appropriate to this investigation for the following reasons:

- The geology of the mining area is complex, and includes a number of local-scale and regional-scale faults which significantly disrupt the strata (refer Figure 2-2 for solid geology). It is possible within a 2-dimensional model to reproduce complex cross-sectional geology, whereas such detail could not be included practically within a 3-dimensional model;
- Seep/W is designed to simulate flow in both the saturated zone and the unsaturated zone. When mining occurs below the phreatic surface[1] an unsaturated zone is induced in the pit walls as seepage to the excavation occurs. Seep/W is well suited to investigation of groundwater level impacts resulting from seepage to open pits, particularly for projects such as Gemini where mine dewatering via bores does not occur, and seepage to the excavation is the only means via which the mine removes water from the groundwater system;
- In open cut mines groundwater storage conditions transition from confined to unconfined in the zone adjacent to the pit walls. Seep/W models the rate of drainage to an excavation via a property called the volumetric water content (refer Section 6.3.2), which is able to accurately account for the rate of groundwater flow and the rate of change of the phreatic surface as groundwater conditions transition from confined to unconfined and gravity drainage of groundwater occurs to the excavation;
- One of the main purposes of the model is to investigate the rate and extent of groundwater level drawdown in response to mining, especially in areas of potentially connected surface water and

[1] The phreatic surface is a line of zero pore water pressure below which all pore spaces are saturated with water, and is analogous to the water table. The term phreatic surface is used throughout this report for consistency with Seep/W modelling terminology.

groundwater systems. This can be readily (and potentially more accurately) achieved through the use of a 2-dimensional cross-section models that are able to accurately represent faulting, relatively thin coal seams and seepage conditions within the mined void;

- The use of 2-dimensional models is valid in cases where the section can be oriented along a groundwater flow line so that all groundwater flow is along the section rather than across it. In open-cut mines where mining occurs below the water table, groundwater flow towards the excavation tends to dominate over the previous regional flow patterns, making it possible to orient a section along a groundwater flow line. Therefore the use of 2-dimensional cross-section models is assessed to be valid for the purposes of this investigation.

The selected modelling platform (Seep/W) is an industry-standard finite-element model capable of modelling groundwater movement and pressure distribution within the saturated/unsaturated zone of porous materials such as soil and rock. Seep/W has been used in this study to predict the rate and extent of change to the phreatic surface in response to the ongoing mining of the already approved Central North Mine, as well as the proposed extension of the operation into the extension area.

Three models were prepared for this study including west-east cross-sectional models through each of the AB and C Pits as well as a long section model that is orientated approximately north-south and represents mining at both pits; the models are described below in Section 6.2. Other details of the models (e.g. hydraulic parameters, boundary conditions, representation of faulting etc.) are discussed in subsequent sections.

6.2 Model Locations and Scenarios

Three models were generated for the study, including:

- A west-east cross section through the C Pit;
- A west-east cross section through the AB Pit; and,
- A long section that runs through the final void of both the C Pit and the AB Pit.

The locations of the sections are shown on Figures 3-1 and 3-2 as well as in Figure 6-1 below.

The models include representation of the mining schedule, including progressive backfilling of the mined areas with spoil, development of the final voids, partial backfilling of the final voids with spoil, and development of the pit void lakes to a level as modelled by WRM (2019). Selected stages in mining are shown below in Figure 6-1 and include:

- Year 1 – Mining commences in the AB Pit in the southwest region of the mining area, with mining progressing to approximately RL-45 in the deepest area, representing a depth of mining of approximately 165 m;
- Year 5 – Mining of the AB Pit has progressed from west to east, to a deepest mined level of approximately -65 mAHD, representing a depth of mining of approximately 185 m. Progressive backfilling of the mined area with spoil has occurred, in conjunction with the development of an out of pit dump;
- Year 9 – Mining of the AB Pit has progressed to the north, with the southern area of mining backfilled with spoil and progressively rehabilitated. The deepest mined area is approximately -65 mAHD, representing a depth of mining of approximately 185 m;
- Year 12 - Mining of the AB Pit has reached the full extent to the north and the floor of the pit is at a level of approximately -45 mAHD, representing a depth of mining in that area of approximately 165 m. Mining of the C Pit has commenced in the west of the mining area;

- Year 16 – Mining of the AB Pit is complete and the final landform has been developed. The final landform includes the partial backfilling of the final void area to a level of approximately 42 mAHD, representing a depth below original ground level of approximately 75 m. Development of the C Pit has progressed to the east and north and the floor is at approximately -50 mAHD, representing a depth below original ground surface of approximately 190 m at that location. Backfilling of the mined area with spoil and development of an out of pit dump has been progressively occurring; and,
- Final Landform (Years 18-20). The final voids are developed for each pit area. The final void levels for the AB Pit are as described above. The final void for C Pit has been partially backfilled with spoil to approximately 65 mAHD, representing a depth below original ground level of approximately 65 m.

The representation of mining in the Seep/W section models is shown on figures from the models and includes:

- Figure 6-2 shows detail of the long section model in the location of the AB Pit, from start of mining to Year 7. Detail from Figure 6-2, which is common to each section model, includes:
  - The coal seams are represented as distinct material types in the model, with the average thickness of each seam represented;
  - Faults are included in the model as they are shown in the sections from the geological model. As discussed in Sections 4.6 and 6.4, the main impact of the faults on groundwater flow occurs when the faults completely truncate the coal seams so that they terminate against lower hydraulic conductivity interburden;
  - The coal measures and overburden are progressively removed from the models in accordance with the mining schedule; and,
  - The mined voids are backfilled with spoil at the rate defined by the mining schedule.
- Figure 6-3 shows detail of the long section model in the location of the AB Pit, from mining Year 8 to end of mining and the final landform. Detail from Figure 6-3, which is common to all model stages that that simulate the final void and final landform, include:
  - The final void is partially backfilled with spoil as a means of reducing groundwater inflow to the final void and reducing the long-term impact on regional groundwater levels (as the water level adjacent to the final void will be to the groundwater level within the spoil and/or final void lake, rather than long-term groundwater drawdown to the base of the final void); and,
  - The average modelled water level within the AB final void of 53.7 mAHD (WRM 2019) has been included as a boundary condition for the post-mining period.
- Figure 6-4 shows detail of the long section model in the location of the C Pit, from commencement of mining in Mining Year 12 to end of mining and the final landform. Detail shown in the model is as described above, with the exception that the final void water level for the C Pit is represented at the average modelled water level of 70.3 mAHD (WRM 2019).
- Figure 6-5 shows the modelled mining sequence at the location of the west-east cross section model through Pit AB, with model detail as described above.
- Figure 6-6 shows the modelled mining sequence at the location of the west-east cross section model through Pit C, with model detail as described above.

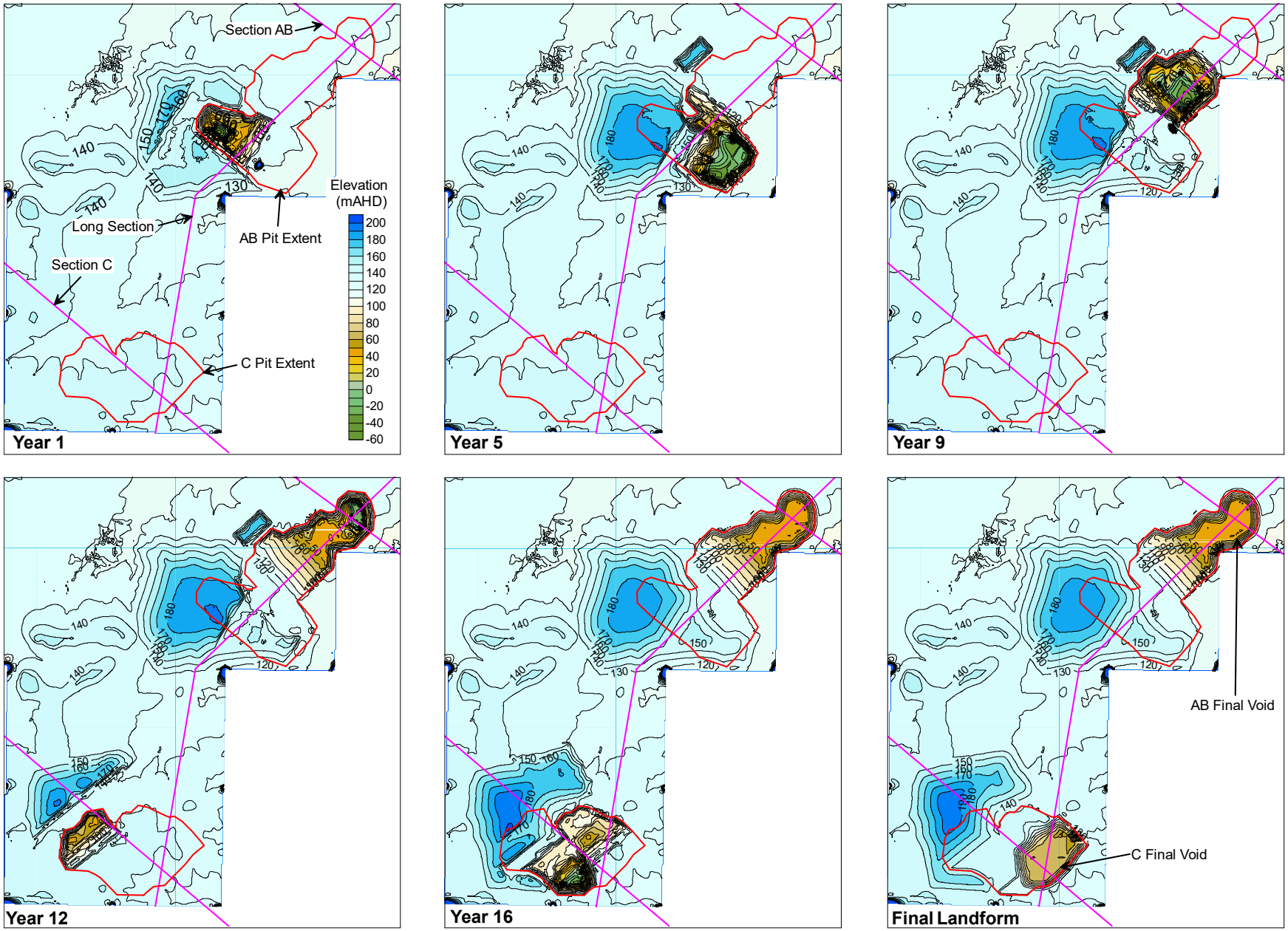

Figure 6-1: Representation of Mining Schedule for Selected Years

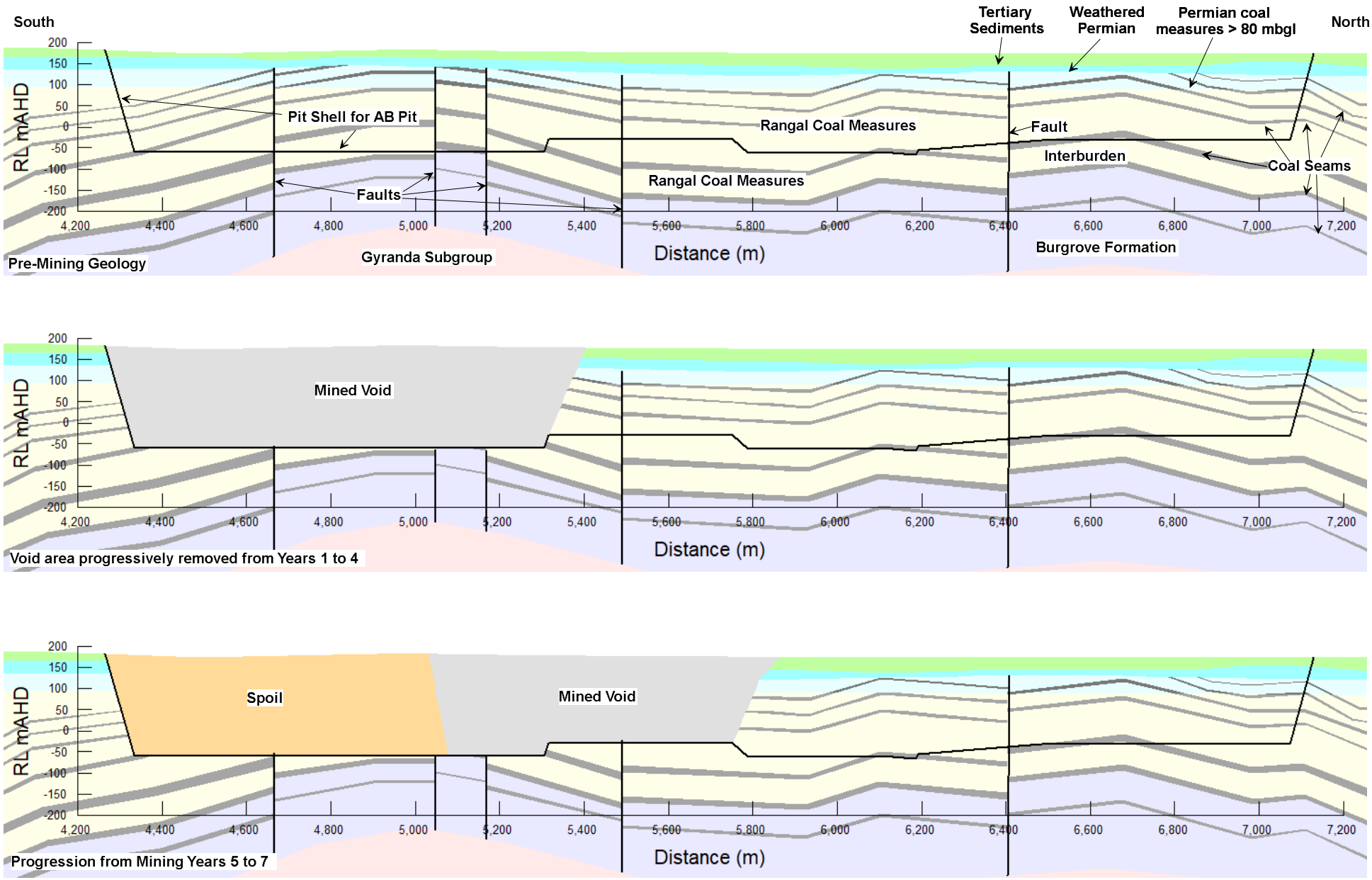

Figure 6-2: Representation of Mining, Long-Section Model, A-B Pit – Start of Mining to Year 7

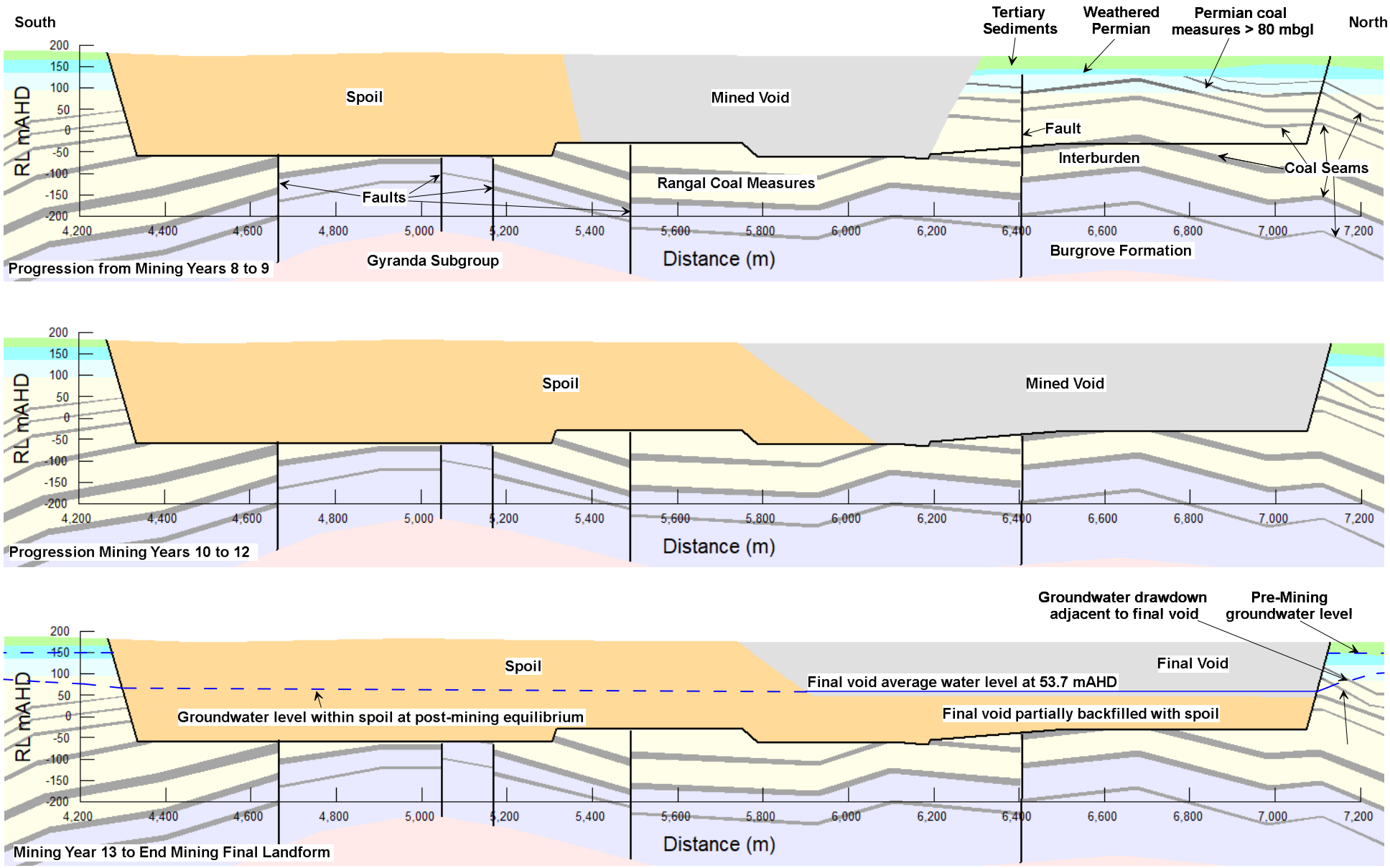

Figure 6-3: Representation of Mining, Long-Section Model, AB Pit – Mining Year 8 to Final Landform

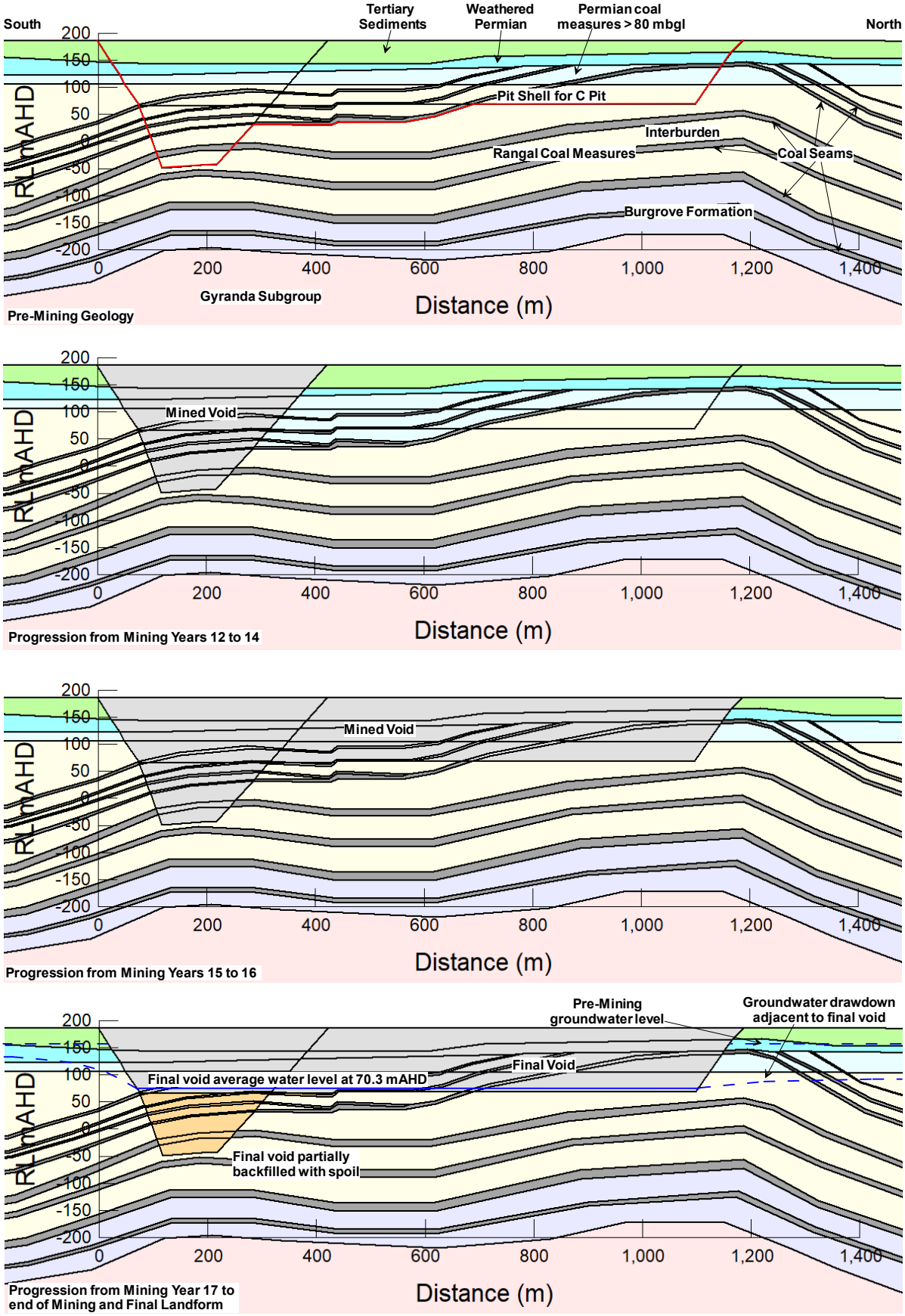

Figure 6-4: Representation of Mining in Long-Section Model – Pit C

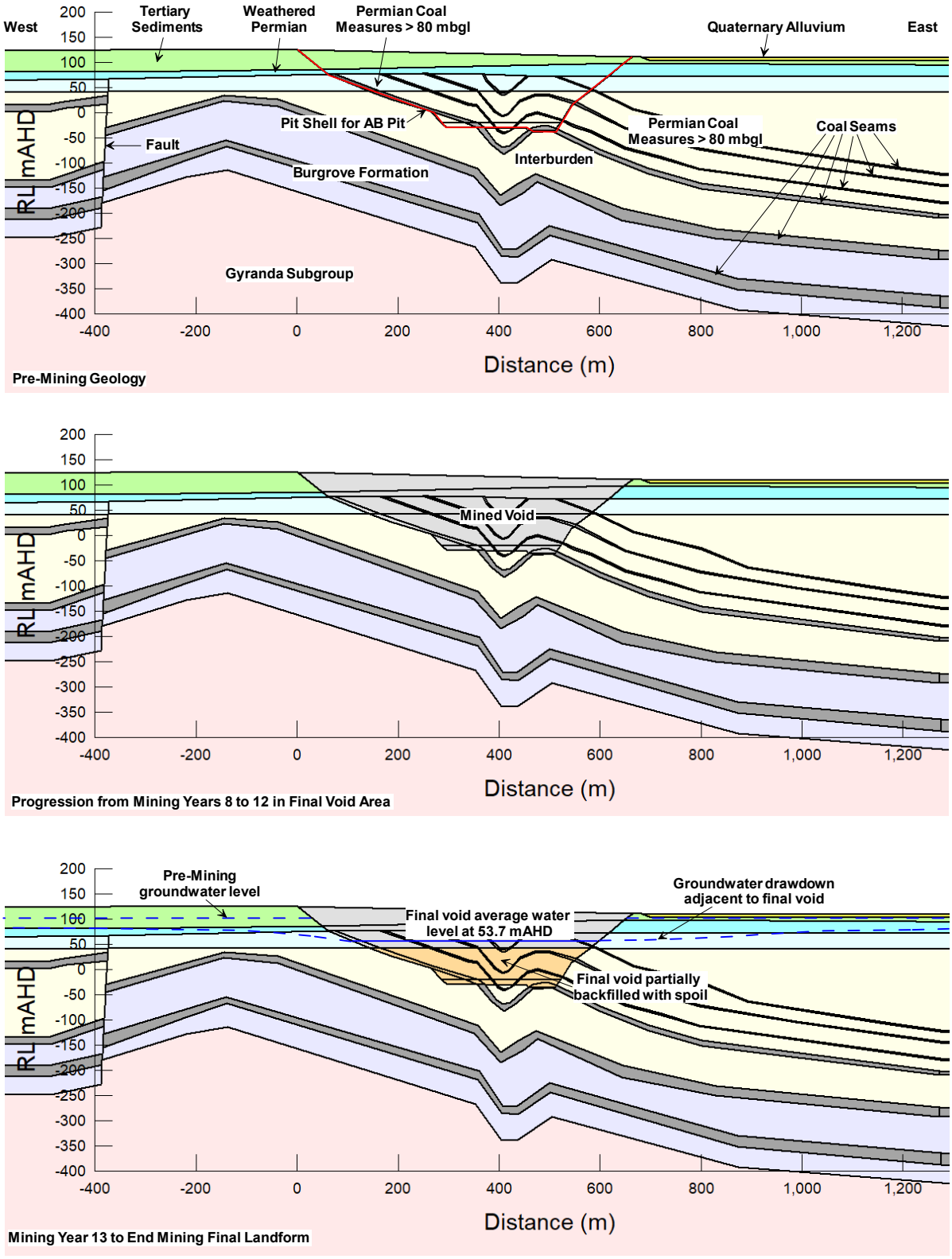

Figure 6-5: Representation of Mining in Cross Section Model through Final Void for AB Pit

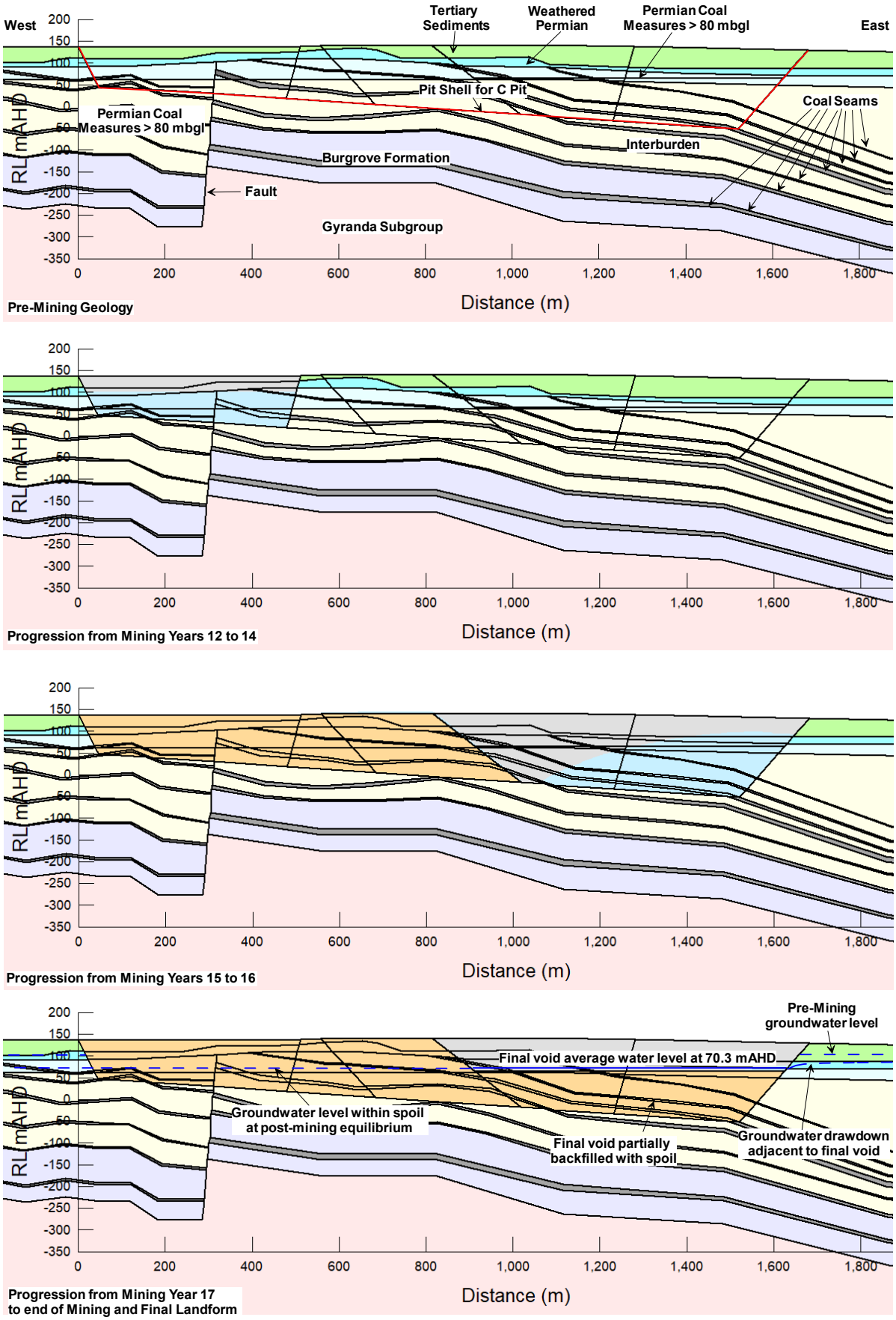

Figure 6-6: Representation of Mining in Cross Section Model for C Pit

6.3 Hydraulic Properties

6.3.1 Hydraulic Conductivity

Based on review and analysis of data discussed in Section 4-4, hydraulic conductivity values have been applied to the base-case model as shown below in Table 6-1.

Table 6-1: Hydraulic Properties Used in Model

Groundwater Unit	K (m/day)	Comment
Quaternary Alluvium	0.1	Value from slug test of bore DW7292W1.
Tertiary	0.27	Geometric mean of data from slug tests (Section 4.4)
Rewan Group	0.002	Estimated K value from other Bowen Basin projects. The Rewan Group is not present in over most of the tenement area but is present in the model area
Coal Seams <80 mbgl	0.37	Geometric mean of slug test data from bores with screened intervals less than 80mbgl
Coal Seams >80 mbgl	0.02	Geometric mean of slug test data from bores with screened intervals greater than 80mbgl
Permian Interburden <80 mbgl	0.01	Value set an order of magnitude higher than the value for interburden below 80 mbgl
Permian Interburden >80 mbgl	0.001	Estimate based on values from slug testing of DW7033W3 (0.002 m/day) and DW7093W2 (recovery rate so slow that the test data could not be analysed)
Mined Spoil	1	Estimate based on professional experience

6.3.2 Volumetric Water Content

6.3.2.1 Specific Yield

Seep/W represents the water content and drainage properties modelled units via a property called volumetric water content, which describes the transition from fully saturated porosity to fully drained porosity. Total porosity comprises specific yield (the volume that will drain from a material under gravity) and specific retention (the volume that will remain within the material following gravity drainage). The specific yield applied to each model unit is shown below in Table 6-2; the specific yield component of the volumetric water content curve is significant for areas close to the open cut void, as previously confined aquifers (such as the Permian coal measures) become unconfined as they drain to the mined void.

Table 6-2: Specific Yield Values used in Model

Lithology	Specific Yield (Sy)
Quaternary Alluvium	0.08 (8%)
Duaringa Formation	0.01 (1%)
Rewan Group	0.01 (1%)
Permian Overburden (weathered)	0.01 (1%)
Permian Overburden (unweathered)	0.01 (1%)
Coal Seams	0.02 (2%)
Permian Interburden	0.01 (1%)
Burngrove Formation and Gyranda Subgroup	0.01 (1%)
Mined Spoil	0.08 (8%)

6.3.2.2 Specific Storage

In Seep/W the specific storage (*Ss*) of the aquifer is accounted for via a related property called the coefficient of volume compressibility (*mv*). In areas where groundwater is draining to the pit void, the

model utilises the specific yield (*Sy*) portion of the volumetric water content curve (as discussed above). With increasing distance from the pit wall the groundwater storage conditions become increasingly confined, Seep/W automatically transitions from unconfined to confined conditions (i.e. from the portion of the volumetric water content curve where pore pressures are at or below atmospheric pressure (and draining to the pit void) to the portion of the curve where pore pressures are positive) using the properties of the Coefficient of Volumetric Compressibility (*mv*). The relationship between the coefficient of volume compressibility (*mv*) and specific storage (*Ss*), can be established from the following equation (Geoslope 2012):

$$S_S = \rho_w g(\alpha + n\beta) = \rho_w g(mv)$$

Where:

Ss	=	Specific Storage
mv	=	Coefficient of volume compressibility
ρw	=	The density of water
g	=	Acceleration due to gravity
α	=	Compressibility of the aquifer skeleton
n	=	The porosity of the aquifer
β	=	Compressibility of water

The value for *mv* generally ranges from 1 x 10^{-6}/ kPa to 1 x 10^{-3}/kPa and for confined aquifers a value of 1 x 10^{-5}/kPa is generally appropriate (Geoslope 2012). An *mv* of 1 x 10^{-5}/kPa has therefore been applied to all groundwater units in the model.

6.4 Representation of Faulting

Faults are represented in the models as follows:

- The site geological model conforms to the solid geology as shown in Figure 2-2. For areas of the model that are beyond the boundaries of the site geological model the solid geology, including fault locations, is consistent with the geology shown on the solid geology map (Figure 2-2).
- Where faults are shown on the sections produced from the site geological model or regional geological data, the location of the faults has been accurately reproduced in the Seep/W models;
- The faults have not been assigned any hydraulic properties, as no quantitative data exists to indicate whether individual faults act as groundwater conduits or as barriers to groundwater flow. Rather, the faults will act as described above, i.e. to allow transmission of groundwater across the fault if more permeable units are connected (such as coal seam to coal seam), and will tend to act as barriers to flow if a conductive unit such as a coal seam is terminated against lower permeability interburden material.

6.5 Boundary Conditions

6.5.1 Recharge

The recharge rate that was applied to the model was based on the recharge calculated via the chloride mass balance (CMB) method, as described above in Section 4.5. The recharge value used was equivalent to 0.1% of average annual rainfall, as an average of the CMB-calculated values for Quaternary sediments of 0.12% of average annual rainfall and the Tertiary sediments of 0.07% of average annual rainfall.

Recharge was applied to transient models as a flux boundary condition applied to the upper layer of the model (representing the ground surface). Rainfall was applied uniformly to the surface formation

(alluvium and Tertiary). Rainfall was not applied to the steady-state model as the starting phreatic surface was generated based on fixed head boundary conditions at the edges of the model.

Rainfall was applied at a rate of 0.678 mm/year, which corresponds to 0.1% of average annual rainfall of 678 mm/year, so that the flux was assigned as:

- 678 mm/year x 0.1% = 0.678 mm/year of recharge = 1.86 x 10^{-6} m/day

6.5.2 Starting Phreatic Surface

The initial phreatic surface was generated in the steady state model by applying fixed heads at the boundaries of the model. The boundaries were set at a distance of approximately 10 km from the edge of mining in order that the boundary conditions did not interfere with the groundwater response to mining, with the boundary conditions set to place the water level within the Tertiary sediments at levels observed from the groundwater monitoring bores for each mining area.

6.5.3 Groundwater Seepage to Voids

Seep/W requires the setting of seepage face review boundary conditions to allow water to leave the model and flow to the mine void. The seepage face boundary a flux boundary with total flux (Q) set at 0 m/day. The area of the mined void is set as a material type with no hydraulic properties; in practice the void is modelled as a zone into which groundwater flow can occur unimpeded through the seepage face boundaries.

6.6 Model Results

6.6.1 Groundwater Level Impacts

The modelled drawdown at the end of mining is shown in Figure 6-7, with the extent of drawdown at post-mining equilibrium (i.e. steady-state post-mining drawdown) shown in Figure 6-8. The contours are shown as the extent of 5 m and 2 m drawdown, based on extrapolation of data points from each of the cross section models (with the location of the data points also shown on Figures 6-7 and 6-8).

These contours have been utilised (refer Section 7.1) to estimate the potential impact on existing groundwater users, based on the definition of bore trigger thresholds for the Queensland *Water Act 2000*. The *Water Act* defines a "bore trigger threshold" (section 362) as *a decline in the water level in the aquifer that is-*

(a) If a regulation prescribes the bore trigger threshold for an area in which the aquifer is situated – the prescribed threshold for the area; or

(b) Otherwise-

i. For a consolidated aquifer – 5 m; or

ii. For an unconsolidated aquifer – 2 m.

The potential for impact on existing groundwater users is discussed in Section 7.1.

The potential for water level impact on environmental values (e.g. groundwater dependent ecosystems) is discussed in Section 7.2.

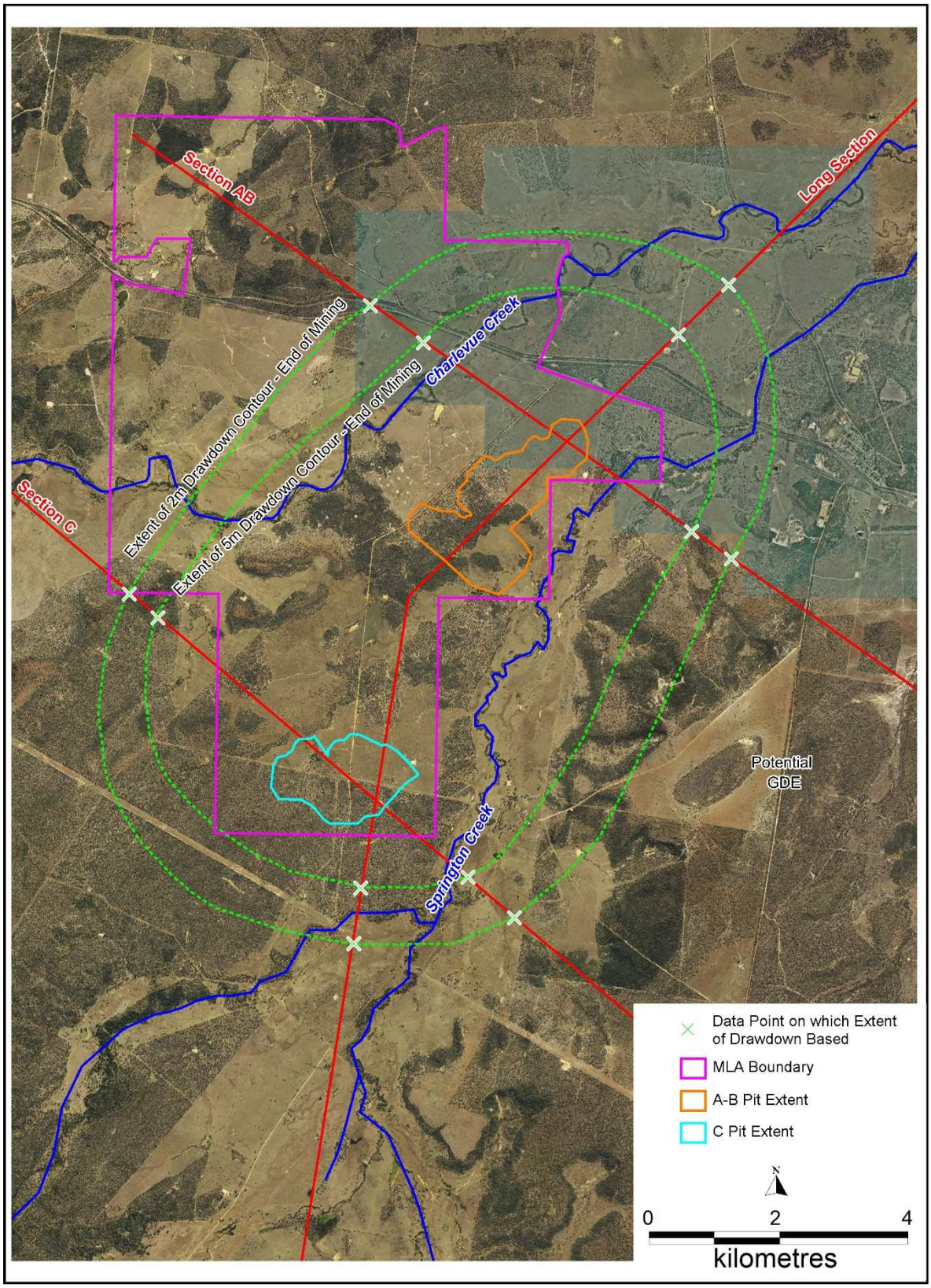

Figure 6-7: Extent of 2 m and 5 m Water Level Drawdown – End of Mining

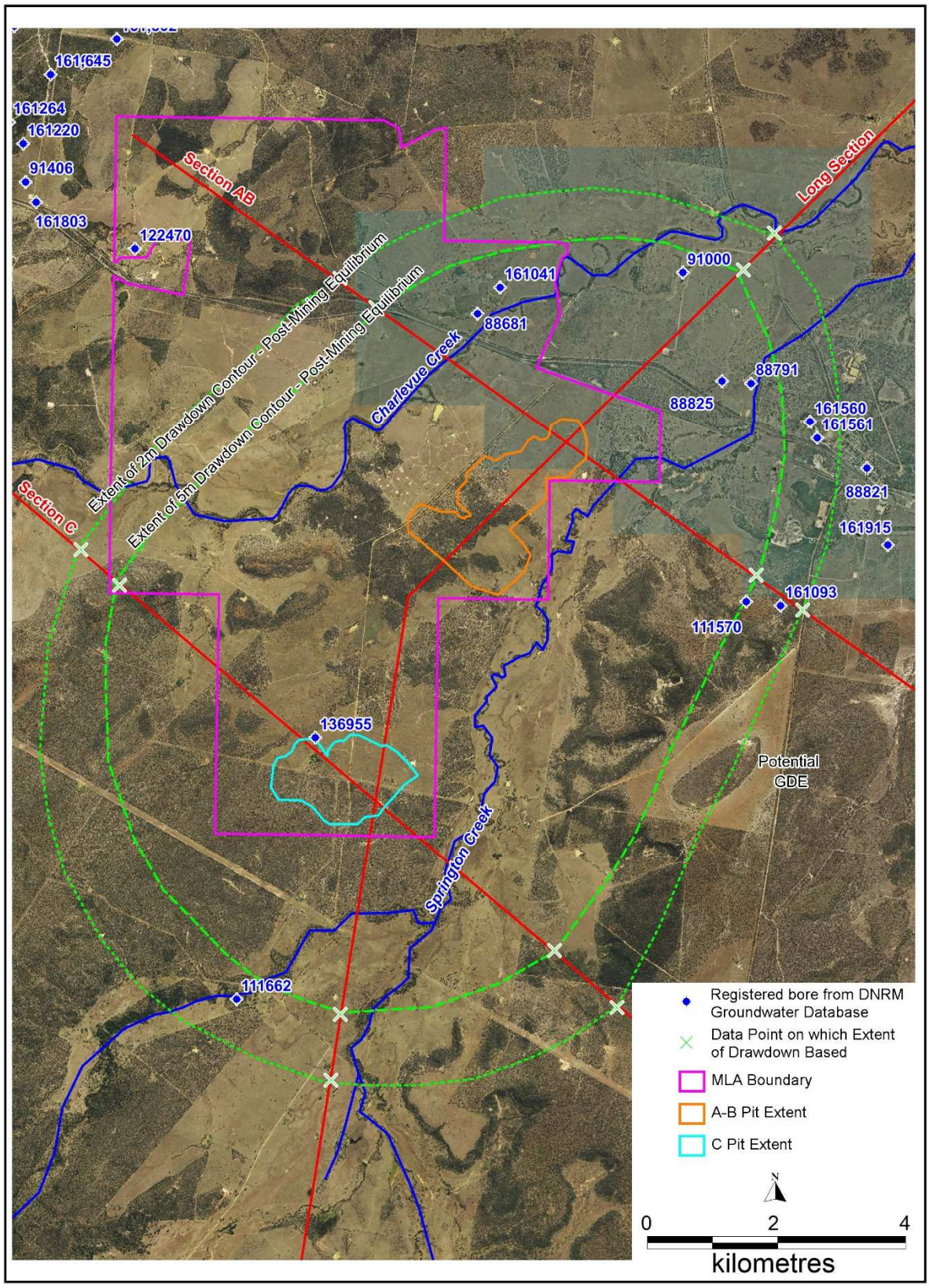

Figure 6-8: Extent of 2 m and 5 m Water Level Drawdown – Post-Mining Equilibrium

6.6.2 Groundwater inflow to the Mined Voids

The rate of groundwater inflow to the mined voids during the operational period of mining has been calculated via the following methodology:

- The seepage rate through the pit walls and floor was calculated within the Seep/W models from the two cross section models (AB Pit Section and C Pit Section) and the long section model for both the AB Pit and C Pit.
- The seepage rate was calculated as the mine development progressed and included the rate of seepage to the mining operation from the backfilled spoil
- The seepage rate, which was calculated on a per-metre basis in the models, was multiplied over the length of pit, using data from the model that was appropriate to each area;
- The modelled inflow rates for each mining year and for each pit are shown below in Table 7-1, in units of both litres per second (L/s) and cubic metres pe day (m^3/day);
- For the purpose of water balance modelling, the effects of evaporation on pit inflows was calculated to provide a value for inflow rates less evaporation (Table 7-1). The evaporation rate was applied using "Morton's estimate of wet environment areal evaporation over land" that was obtained for the project area from the SILO datadrill. This evaporation dataset was used for calculating evaporation from the pit walls and floor, based on advice from the project hydrologist WRM (M Batchelor pers. comm.). Evaporation was applied to the modelled inflow using a pan factor of 0.8 for the surface of the pit, decreasing linearly to a pan factor of 0.5 at the base of the pit (with the lower evaporation at the base of the pit due to shading etc.). The net inflow rate to each pit (modelled inflow less evaporation) is shown in Table 7-1.

Other observations/ notes with respect to the calculated inflow rates are as follows:

- The increase in the modelled and net inflow rate in years 11 and 12 of the AB pit is due to groundwater from the spoil reporting to the final void area. The spoil was modelled as being placed dry (fully-drained but with a residual water content); the groundwater level in the spoil increased over time due to inflow from the floor and walls of the mined area, as this inflow rate was not subject to evaporation. In addition, the rate of recharge to the spoil occurs at a rate that is higher than the natural ground, allowing a water table to develop within the spoil. By mining years 11 and 12 the water level within the spoil had developed to a level that allowed relatively significant rates of inflow to occur.
- For the purpose of future associated water reporting it is concluded that it would be more reasonable to assume the rate of inflow prior to development of the spoil aquifer (i.e. ~5.7 L/s or ~500 m^3/day) as the water that is developed from the spoil is derived mainly from rainfall recharge to the spoil and does not represent water from the natural formation.
- The modelled inflow rate and net inflow rate (less evaporation) reduces significantly in mining years 17 and 18 for the AB Pit and at mining year 18 for the C Pit. This is due to the partial backfilling of the final void area with spoil.
- For the post-mining years the net groundwater inflow rate is zero, as the rate of inflow from the pit walls above the backfilled area of spoil and the final void lake occurs at such a low rate that the rate of evaporation is significantly greater than the modelled rate of inflow.

Table 6-3: Calculated Rates of Inflow to the AB Pit and C Pit

Year	AB Pit				C Pit			
	Modelled Inflow Rate		Less Evaporation		Modelled Inflow Rate		Less Evaporation	
	L/s	m3/day	L/s	m3/day	L/s	m3/day	L/s	m3/day
1	7.2	626	1	86				
2	7.2	626	1	86				
3	5.0	433	1	86				
4	5.0	433	1	86				
5	5.9	508	1	86				
6	5.9	508	1	86				
7	11.0	946	1	86				
8	11.0	946	1	86				
9	5.7	493	1	86				
10	5.7	493	1	86				
11	18.0	1554	7	605				
12	18.0	1554	7	605	1.4	121	0	0
13	13.7	1181	6	518	1.4	121	0	0
14	13.7	1181	6	518	2.8	241	0.5	43
15	5.2	453	0.5	43	2.8	241	0.5	43
16	5.2	453	0.5	43	2.8	239	0.5	43
17	2.9	248	0.5	43	2.8	239	0.5	43
18	2.9	248	0.5	43	1.9	163	1	86

6.7 Uncertainty Analysis

6.7.1 Introduction

A sensitivity analysis of the groundwater model developed for the Gemini Project has been undertaken with reference to the following documents:

- Barnett et al. (2012) *Australian Groundwater Modelling Guidelines*. Sinclair Knight Merz and National Centre for Groundwater Research and Training, Waterline Report Series No. 82, June 2012; and,
- Middlemis, H. & Peeters, L.J.M. (2018) *Explanatory Note, Uncertainty Analysis in Groundwater Modelling*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy (Draft).
- Reilly, T.E. & Harbaugh, A.W. (2004) *Guidelines for Evaluation of Groundwater Flow Models.* United States Geological Survey, Scientific Investigations Report 2004-5038.

A groundwater model sensitivity analysis involves the evaluation of model input parameters to see how much they affect model outputs, which are heads and flows (Reilly & Harbaugh 2004). The process of sensitivity analysis can be conducted manually or automatically; in the manual approach, multiple model simulations are made in which ideally a single parameter is adjusted by an arbitrary amount (Reilly & Harbaugh 2004). The emphasis of sensitivity modelling is on determining how sensitive the model is to each parameter tested, using a non-technical interpretation of “sensitive” (Barnett et al. 2012).

The explanatory notes for uncertainty analysis that were prepared for the IESC (Middlemis & Peeters 2018) outline three general approaches to uncertainty analysis; these are, in order of increasing complexity:

1. Scenario analysis with subjective probability;
2. Deterministic modelling with linear probability quantification; and,
3. Stochastic modelling with Bayesian probability.

The first method (scenario analysis with subjective probability) has been applied to this modelling study. This methodology is judged to be appropriate to the analysis of a Seep/W model, which utilises a single set of parameters for each material type. A sensitivity analysis of the Gemini Project model was undertaken as follows:

- The base-case models were used to establish the extent of 5 m drawdown from the edge of the final voids to the north, south, east and west of the mining area. The location of the section models, as well as detail from the models pre and post-mining, are shown in Figures 3-1 and 3-2. The sections highlight the relationship between the various groundwater units, including the degree to which faulting and folding compartmentalises the units (as shown from Figures 6-1 to 6-6, which show detail of the cross section models in the area of mining);
- The base-case model was altered to make changes to specific parameters (discussed below) and to assess the impact that the change in parameters had on the location of the extent of the 5 m drawdown contour at the post-mining equilibrium.
- The parameters that were selected for the sensitivity analysis are summarised below in Table 6-4 and include:
    - Horizontal hydraulic conductivity (Kh;
    - Vertical hydraulic conductivity (Kz);
    - Specific yield (Sy) and coefficient of volume compressibility (*mv*) (which is related to the aquifer specific storage (Ss), as described in Section 6.3.2.2); and,
    - Recharge.

6.7.2 Results

The results of the sensitivity analysis are discussed below and are presented in Table 6-4 and on Figure 6-8, which shows the extent of the 5 m post-mining equilibrium drawdown contour for each uncertainty analysis parameter. Results are summarised as follows:

- The model is assessed to be most sensitive to changes in horizontal hydraulic conductivity (Kh) and recharge, with results as follows;
    - An increase in the Kh of the Permian coal measures (coal seams and interburden) by a factor of 10 results in an increase in the extent of the 5 m drawdown contour at post-mining equilibrium years post-mining of between 800 m (to the east of C Pit) and 2,000 m (to the south of C Pit), as shown on Figure 6-8. The variability in the extent of the 5 m drawdown contour is related to dominant rock type in each direction and the variability in faulting, folding and dip direction of the coal measures. The drawdown contours also extend further to the north/south than to the east/west. This is interpreted to be related to:
        - The more continuous extension of coal seams along geological strike, as the coal seams have a higher permeability than the interburden and are the main conduits for groundwater flow within the coal measures; and,

        - The steep dip of the coal seams to the east and west, as a component of the drawdown will be acting in a direction that includes a combination of the Kh and the lower hydraulic conductivity Kz of the unit.

    - An increase in the recharge by a factor of 10, from 0.1% of average annual rainfall to 1% of average annual rainfall, results in a reduction in the extent of drawdown of between -550 m (to the west of Pit C) and -1,300 m (to the east of Pit C). The variability in the impact of the change in recharge is interpreted to be related to factors such as the thickness of Tertiary sediments and the weathered Permian sediments, in conjunction with the factors such as folding and faulting that also impact the other parameters tested.

- The model is relatively sensitive to changes in vertical hydraulic conductivity (Kz); an increase in the Kz of the Permian coal measures (interburden and coal seams) by a factor of 10 results in an increase in the extent of 5 m drawdown of between approximately 100 m (to the west of C Pit) to 670 m (to the south of C Pit);
- An increase in the storage properties (specific yield (Sy) by a factor of 2 and coefficient of volume compressibility (*mv*) by a factor of 10) results in a decrease in the extent of the 5 m drawdown contour relative to the base case of between -330 m (to the north of AB Pit) and -1,200 m (to the east of C Pit).

  Because the specific yield component of storage only acts locally (i.e. close to the walls of the open cut), the main impact on drawdown is related to the change in the coefficient of volume compressibility (*mv*). A lower value for *mv* (and hence *Ss*) indicates a geotechnically stiffer (less compressible) aquifer; by contrast an increase in the aquifer *mv* (and hence *Ss*), as undertaken in the uncertainty analysis, will result in a more compressible aquifer, which in turn will act to decrease the extent of drawdown.

Table 6-4: Results of Uncertainty Analysis

Scenario	Description	Base Case	Sensitivity Model	Change (m) in extent of 5 m drawdown contour*	
Long Section Model through AB Pit and C Pits				**North of AB Pit**	**South of C Pit**
1	Increase Kh of Permian Interburden <80 mbgl x 10	0.01 m/day	0.1 m/day	1,800	2,000
	Increase Kh of Coal Seams < 80 mbgl x 10	0.37 m/day	3.7 m/day		
	Increase Kh of Permian Interburden >80 mbgl x 10	0.001 m/day	0.01 m/day		
	Increase Kh of Coal Seams >80 mbgl x 10	0.02 m/day	0.2 m/day		
2	Increase Kz of Permian Interburden <80 mbgl x 10	0.001 m/day	0.01 m/day	450	670
	Increase Kz of Coal Seams < 80 mbgl x 10	0.037 m/day	0.37 m/day		
	Increase Kz of Permian Interburden >80 mbgl x 10	0.0001 m/day	0.001 m/day		
	Increase Kz of Coal Seams >80 mbgl x 10	0.002 m/day	0.02 m/day		
3	Increase specific yield (*Sy*) of Permian Interburden x 2	0.02 (2%)	0.04 (4%)	-330	-430
	Increase specific yield (*Sy*) of coal seams x 2	0.01 (1%)	0.02 (2%)		
	Increase storage coefficient (*Ss*) of Permian coal seams and Interburden x 10	1×10^{-5}	1×10^{-4}		
4	Increase Recharge x 10	0.1% of rainfall	1% of rainfall	-650	-1200
AB Pit Cross Section Model				**West of AB Pit**	**East of AB Pit**
1	Increase Kh as described above	As above	As above	1,000	1,200
2	Increase Kz as described above	As above	As above	350	440
3	Increase Sy and Ss as described above	As above	As above	-930	-700
4	Increase recharge as described above	As above	As above	-1,400	-1,200
C Pit Cross Section Model				**West of C Pit**	**East of C Pit**
1	Increase Kh as described above	As above	As above	900	800
2	Increase Kz as described above	As above	As above	100	210
3	Increase Sy and Ss as described above	As above	As above	-800	-1200
4	Increase recharge as described above	As above	As above	-550	-1,300

* A positive value indicates an increase in the extent of drawdown, a negative value indicates a decrease in the extent of drawdown

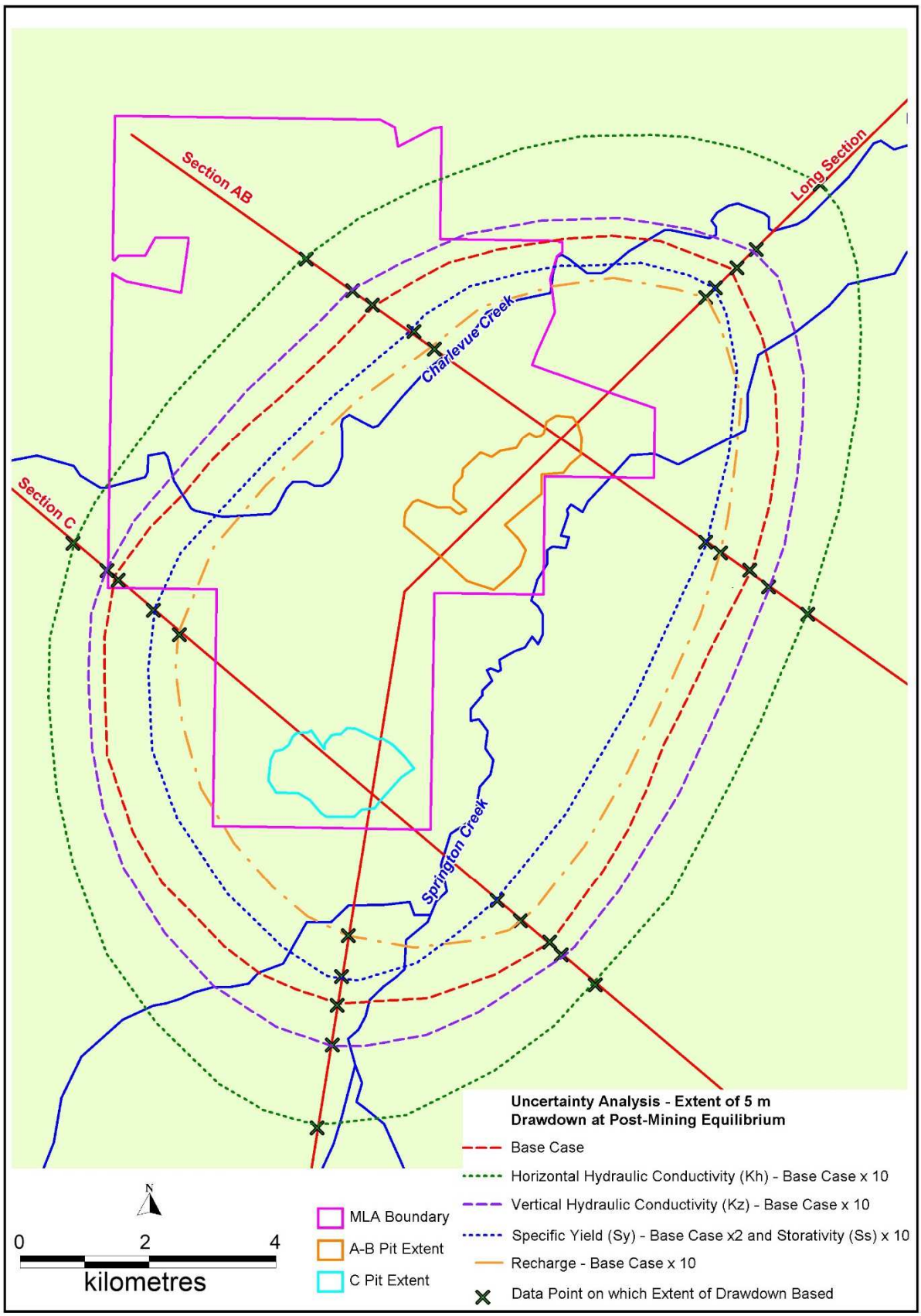

Figure 6-9: Uncertainty Analysis

7.0 GROUNDWATER IMPACTS FROM MINING

7.1 Impacts on Existing Groundwater Users

Figures 6-7 and 6-8 show the location of eleven (11) registered groundwater bores (bores from the DNRM groundwater database that are listed as being either existing or abandoned but useable) within the 2 m drawdown zone at end of mining (Figure 6-7) and/or at post-mining equilibrium (Figure 6-8). Summary data for the bores within this zone are shown below in Table 7-1. In summary:

- Bores 136955 and 11662 are located on land that is owned by Magnetic South (the proponent for the Gemini project);
- Two bores (161560 and 161561) appear to be monitoring bores for the Dingo Landfill;
- A number of bores record groundwater that is highly saline and assessed to be of no beneficial use (as discussed in Section 4.3, an EC of 6,000 µS/cm is assessed to be the upper limit of salinity tolerance for beef cattle, sheep, horses and pigs with no loss of production (ANZECC 2000), with a decline in animal health at progressively higher salinity values. Bores 88681, 88791 and 91000 record EC values of 10,000 µS/cm, 19,200 µS/cm and 14,660 µS/cm respectively, and on this basis are assessed to have little to no beneficial use);
- Bores that remain in the area of potential impact (i.e. that are not discussed in the above dot points) include:
    - Bores 88825 and 161041, which are sites with relatively little available data, but which are located within the zone of potential impact to the northeast and west-northwest of AB Pit respectively;
    - Bores 111570 and 161093 also record relatively fresh groundwater (<1,000 µS/cm) at shallow depth. While these bores are located within the extent of 2 m drawdown, these bores are also assessed to be isolated from the regional groundwater system (refer discussion in Section 7.2.1 below)

At sites including 111570 and 161093 it is noted that the sites are not located within the zone of potential impact at end of mining, but are within the zone of potential impact at post-mining equilibrium.

Notwithstanding the time that it may take for drawdown impacts to be observed at the private groundwater bores listed in Table 7-1, it is recommended that a bore survey be undertaken on the potentially impacted properties (as defined by the extent of 2 m drawdown contour on Figure 6-8).

It is further noted that make-good agreements may be required for groundwater bores within the zone of potential impact in the event that groundwater level drawdown affects the utility of the bores.

Table 7-1: Bores from DNRM Groundwater Database within 2m Drawdown Zone

RN	Aquifer	EC (µS/cm)	SWL (mbgl)	Original Bore Name	Comment
88681	Duaringa Formation	10000			Located within MLA - land owned by Magnetic South
88791	Duaringa Formation	19200	-20	New Bore	Extremely saline - no beneficial use based on water quality
88825	Unknown			Windmill	
91000	Duaringa Formation	14660	-20	Mackenzie OLO	Extremely saline - no beneficial use based on water quality
111570	Tertiary-Undefined	240	-16	Ward	Refer Section 7.2.1 for discussion
111662	Tertiary-Undefined	750	-17	Smith	Located within land owned by Magnetic South
136955	Tertiary-Undefined	10300	-21		Located within MLA - land owned by Magnetic South
161041	Duaringa Formation		-29		
161093	Tertiary Mafic Volcanics	710	-19.5		Refer Section 7.2.1 for discussion
161560	Unknown	28102		Dingo Landfill MW2	Assumed to be monitoring bore at Dingo Landfill
161561	Unknown			Dingo Landfill MW1	Assumed to be monitoring bore at Dingo Landfill

7.2 Groundwater Dependant Ecosystems

7.2.1 Area of Mapped Potential GDE to East of MLA

A potential groundwater dependant ecosystem (GDE) has been mapped to the east of the MLA and is shown below in Figure 7-1. The following observations and comments are made with respect to the potential GDE:

- The top plot on Figure 7-1 shows the potential GDE from an aerial photograph as an ovaloid feature with an area of approximately 82 ha that is located approximately 4 km east of the MLA boundary.
- The bottom plot on Figure 7-1 shows the potential GDE underlain by contours of surface topography and includes water level data from available groundwater bores. From this plot it is noted that:
  - The surface elevation of the eastern area of the MLA is in the range 125 to 135 mAHD, with the elevation of the Springton Creek floodplain dropping below 120 mAHD in the area between the MLA boundary and the potential GDE;
  - The potential GDE is located on an elevated ridgeline; the feature is located within a shallow depression on the ridgeline that is surrounded to the south, west and east by elevation contours at 170 mAHD, with the central of the depression falling below 165 mAHD. This area drains to the northeast via a narrow zone that is at a surface elevation of approximately 167 mAHD.
- The potential GDE is therefore located within a shallow depression on the ridgeline that is likely to be internally draining under average rainfall conditions and that only discharges to the northeast under high rainfall conditions. It is interpreted that, under average rainfall conditions and at the tail end of high rainfall conditions, surface runoff within the relatively small catchment that reports to this area will pond in the area of the shallow depression and provide localised recharge to an

underlying groundwater lens that is likely to be disconnected from the regional groundwater system (discussed further below).

- The bottom plot on Figure shows available groundwater level data from site monitoring bores (water levels from July/August 2019 – refer Table 4-1) as well as from two registered groundwater bores from the DNRM groundwater database). The date of the groundwater measurement for the two registered bores is likely to be from the time of drilling/construction; bore 111570 was constructed in November 2001 and bore 161093 was constructed in August 2014 (refer Table 4-5 of this report). From the water level data shown on Figure 7-1 it is observed that:
  - The depth to water for bores constructed within Tertiary sediments and Permian coal measures ranges from 26.25 to 32.37 mbgl in this area (Figure 7-1 shows data for the shallowest bore in this area; the Tertiary bore at the location of DW7105W2 is dry). Based on the elevation at these sites, this equates to a groundwater elevation of 108-110 mAHD for bores in topographically elevated areas (DW7093W1 and DW7225W1) to 89.59 mAHD at bore DW7282W1 (located in a topographically lower area of the MLA adjacent to Springton Creek).
  - The water level in alluvium bore DW7292W1 is 11.19 mbgl, which equates to an elevation of 102.39 mAHD;
  - The water level in the site monitoring bores, which are assessed to be representative of the regional groundwater level, are therefore considerably lower than the elevation of the base of the potential GDE, which is at an elevation approximately 165 mAHD;
- The water level in the two private bores to the north of the potential GDE (16 mbgl at 111570 and 19.5 mbgl at 161093) equates to a groundwater elevation of 132 to 144 mAHD at these sites.
- Based on the observations discussed above, it is concluded that:
  - The potential GDE is located on an elevated ridgeline, but within a shallow depression that is likely to drain internally under average rainfall conditions but drains to the northeast under high rainfall conditions;
  - The drainage of surface runoff to the shallow depression is likely to result in localised recharge to a perched lens of groundwater that is disconnected from the regional groundwater system;
  - It is probable that this perched groundwater lens provides water to vegetation within the depression during the dry season, but that the groundwater lens is an extremely localised system that relies on replenishment by seasonal rainfall rather than being maintained by the regional groundwater system
- It is noted the EC of site groundwater monitoring bores, which are interpreted to be within the regional groundwater system, is high (15,000 µS/cm to 29,000 µS/cm – refer Section 4.3). However it is also noted that the EC of the registered bores to the north of the potential GDE is very low, with bore 111570 recording an EC of 240 µS/cm and bore 161093 recording an EC of 710 µS/cm. This is interpreted to provide further evidence that the groundwater system in this area is perched above the regional groundwater system, with the flowline from the area of the potential GDE (where recharge is interpreted to occur) to the area where these bores are located being very short.
- From the groundwater modelling data presented in Section 6.7.2 and Figure 6-8, it is noted that the 2 m drawdown contour at post-mining equilibrium extends under the area where the potential GDE is located. It is interpreted that the risk posed by drawdown from the mining operation to the potential GDE is very low, as:
  - It is interpreted that the potential GDE exists in an area where the groundwater system is very localised and is perched above the regional groundwater system; and,

  - The groundwater lens that is interpreted to be located beneath the potential GDE is likely to be maintained by seasonal surface water runoff rather than the regional groundwater system.

- It is noted that, based on the evidence available to date, it cannot be conclusively stated that the groundwater system is not continuously saturated from the area below the potential GDE (at RL165 mAHD to the regional groundwater system (at an elevation of 110 to 89 mAHD). However, based on professional experience and judgement, it is considered that:
  - It is most probable that the ridgeline and the potential GDE is underlain by a perched groundwater system and,
- In any case it is interpreted that the potential GDE is maintained by localised runoff and shallow recharge and that a reduction in the regional groundwater level of approximately 2 m, at a vertical distance of approximately 50 to 60 m below the base of the potential GDE, has a very low risk of impacting groundwater levels beneath the potential GDE.

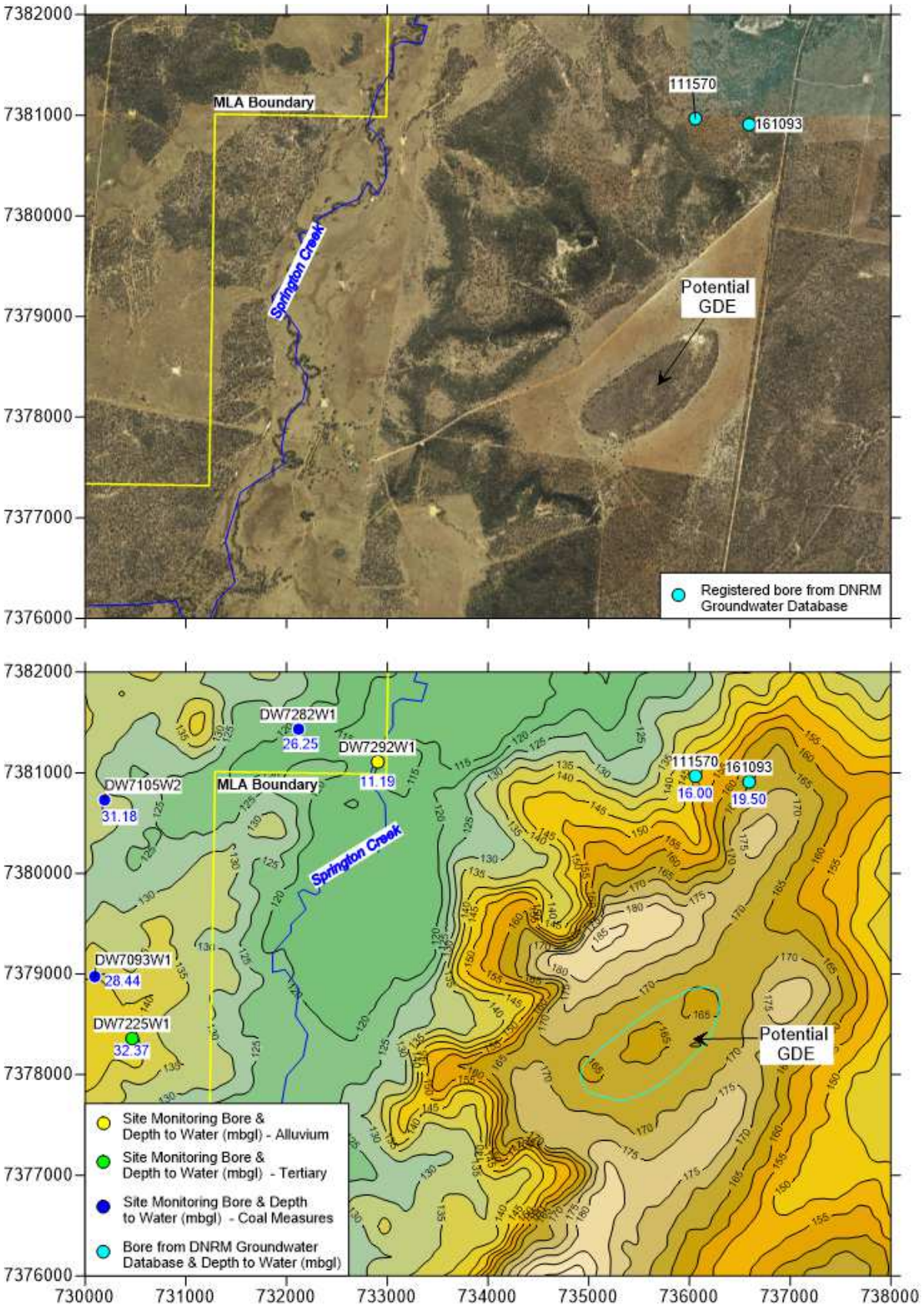

Figure 7-1: Assessment of Potential GDE to East of the Gemini Project MLA

7.2.2 GDE's Associated with Watercourses and Floodplains

A number of potential GDE's in the Project area are riverine-type wetlands that include riparian vegetation on watercourses and floodplains. It is understood from the ecological assessment (reference) that the riverine vegetation includes tree species such as blue gum (*Eucalyptus tereticornis*) and River oak (*Casuarina cunninghamiana*). With respect to the potential for the mining operation to impact this type of potential GDE the following observations are made:

- The water level drawdown associated with mining is predicted to be in excess of 5 m at some locations below both Charlevue Creek and Springton Creek (Section 6.6.1, Figures 6-7 and 6-8). It cannot be ruled out that drawdown from mining may affect water levels in the alluvium at some locations.
- This section therefore considers the potential for vegetation within the Project area to be currently dependent on groundwater, either totally or partially, which will then inform the risk to vegetation in the event that groundwater level drawdown from mining does impact groundwater levels within the alluvium.
- The assessment of current dependence of vegetation on groundwater considers both groundwater level and groundwater quality; these considerations are summarised as follows:
  - Groundwater level considerations:
    - It is understood from the ecological assessment (reference) that blue gum has a rooting depth of up to 10 m.
    - The measured depth to groundwater in the alluvium bores close to the creeks is between 8.77 m (DW7076W, adjacent to Charlevue Creek) and 11.19 m (bore DW7292W1, adjacent to Springton Creek). It is noted that the groundwater level is likely to be somewhat closer to ground surface at the invert (i.e. central line) of the creeks than in the bores, which are constructed outside the main creek channel.
    - Therefore, while the groundwater level is assessed as being close to the maximum depth that could be accessible by vegetation, it cannot be conclusively ruled out that the groundwater level is beyond the depth that is accessible to the root zone of some plants.
    - In addition, the seasonal range of water level within the alluvium is currently unknown. However, it is noted that bore DW7076W (adjacent to Charlevue Creek) is currently fitted with a datalogger (refer Section 4.2 and Figure 4-4) and that bore DW7292W1 (adjacent to Springton Creek) is programmed to be fitted with a datalogger; this data will allow assessment of the range of water level within the alluvium and the response of groundwater levels within the alluvium to rainfall recharge and stream flow events.
  - Groundwater quality considerations
    - As noted above, the riverine vegetation includes tree species such as blue gum (*Eucalyptus tereticornis*) and River oak (*Casuarina cunninghamiana*). With reference to available online information[1] it is noted that the species listed above are described as being tolerant of moderately saline conditions, which are defined[1] as being in the range of 4,000 to 8,000 µS/cm;
    - The measured EC of groundwater within the alluvium is relatively high, with a range from 15,200 µS/cm to 16,600 µS/cm for bore DW7076W (adjacent to Charlevue Creek) and a single field value for bore DW7292W1 of 5,948 µS/cm (adjacent to Springton Creek).

[1] http://www.plantstress.com/articles/salinity_m/salinity_m_files/salt%20tol%20australia.htm

- It is therefore assessed that, based on available EC data, the groundwater within the Charlevue Creek alluvium is too saline to be useable by the vegetation that occurs along the creek.
- The EC at bore DW7292W1 is within the range that is potentially useable by moderately salt-tolerant plants, but it is also noted that the depth to groundwater in that area (11.19 mbgl) is potentially beyond the depth that is accessible by vegetation.

Figure 7-2 (below) shows two photos that were taken at the time of airlift development of bore DW7076W, which is constructed within alluvium adjacent to Charlevue Creek. With reference to the photos in Figure 7-2 and the information outlined above, it is observed that:

- The photo on the left of Figure 7-2 shows bore DW7076W, with the trees in the background located within the or adjacent to the channel of Charlevue Creek;
- The photo on the right of Figure 7-2 shows vegetation within the channel of Charlevue Creek;
- Noting that the EC of groundwater in the Charlevue Creek alluvium at bore DW7076W is within the range of 15,200 µS/cm to 16,600 µS/cm, it is concluded that the groundwater at this site is too saline for use by the vegetation within the creek;
- However, the vegetation within and adjacent to Charlevue Creek appears healthy; on this basis it could be concluded that the vegetation is likely to subsist on water that becomes available following wet-season flow events in Charlevue Creek, and the soil moisture and/or perched groundwater that may exist for some time after flow events in the creek, rather than on the water table that exists at greater depth where the water is highly saline.

Figure 7-2: Alluvium Bore DW7076W and Charlevue Creek adjacent to Bore

On the basis of the above assessment, it is concluded that:

- Groundwater level drawdown from the proposed mining operation will extend beneath Charlevue Creek and Springton Creek and it cannot be ruled out that drawdown from mining may affect water levels in the alluvium at some locations.

- The riparian vegetation at site (within both Charlevue Creek and Springton Creek) is likely to subsist on water that becomes available following wet-season flow events in the creeks, and on the soil moisture and/or perched groundwater that may exist for some time after flow events in the creek, rather than on the water table that exists at greater depth (in the range of 9 to 11 m, based on available data) where the water is moderately to highly saline (and in the case of data for the Charlevue Creek alluvium, too saline to be tolerated by the vegetation species that line the creek);
- Therefore, even if mining does impact on groundwater levels within the alluvium, the risk of impacts to existing riparian vegetation is assessed to be very low, as it is assessed that it is unlikely that the vegetation is dependent on groundwater for survival.

Notwithstanding the above assessment, ongoing monitoring of groundwater levels is recommended, with a recommendation that bores within the alluvium are monitored via water level dataloggers to allow assessment of the range of seasonal water level variation at these sites. It is noted that a data logger is already fitted to bore DW7076W and that it is planned to install a logger in bore DW7292W1

7.3 Cumulative Impacts

There are no mining operations within the zone of predicted drawdown from mining at the Gemini Project site; it is therefore concluded that there are no cumulative impacts to assess.

7.4 Impacts on Groundwater Quality

Groundwater modelling (Section 6.0) predicts that a permanent cone of depression will develop that will direct groundwater flow towards the final voids; therefore, the risk of the project impacting on water quality (via outflow to the groundwater system) is assessed to be low.

It is, however, assessed that the Project could impact groundwater quality if the water within the final void were able to exit the void via unconsolidated sediments (i.e. the base of Tertiary) and flow via the groundwater system towards sensitive environmental receptors such as Springton Creek. For this reason, an assessment of the potential for water within the final voids to exit the void via the base of Tertiary sediments has been undertaken as follows:

- Contours for the base of Tertiary sediments was obtained for the area of the AB Pit and C Pit from the site geological model;
- The final void water level was obtained for each of the final voids from the WRM surface water assessment report (WRM 2019) and was assessed for:
  - The maximum final void water level for the Base Case; and,
  - The maximum final void water level for the High Inflow Case.
- The data for each mining area was assessed to establish whether any pathways existed for water to exit the final void via the base of Tertiary sediments, for the maximum Base Case and maximum High Inflow Case final void water levels.

The results of the assessment are summarised as follows:

- Assessment of the AB Pit:
  - Figure 7-3 shows the base of Tertiary contours for the area around the AB Pit and includes:
    - The limit of mining within the AB Pit;
    - The location of the final void;
    - The area of the final void that is within the area of inundation at the maximum water level for the High Inflow Case of 64.7 mAHD;

- The location of the closest environmental receptor (Springton Creek), which occurs to the east of the AB Pit.

- From the assessment it is concluded that:
  - The lowest level for the base of Tertiary adjacent to the AB Pit mining area and final void area is approximately 70.5 mAHD (as shown on Figure 7-3);
  - The base of Tertiary is therefore approximately 6 m higher than the maximum water level for the High Inflow Case;
  - There is no outlet for water within the final void of the AB Pit via the base of Tertiary sediments

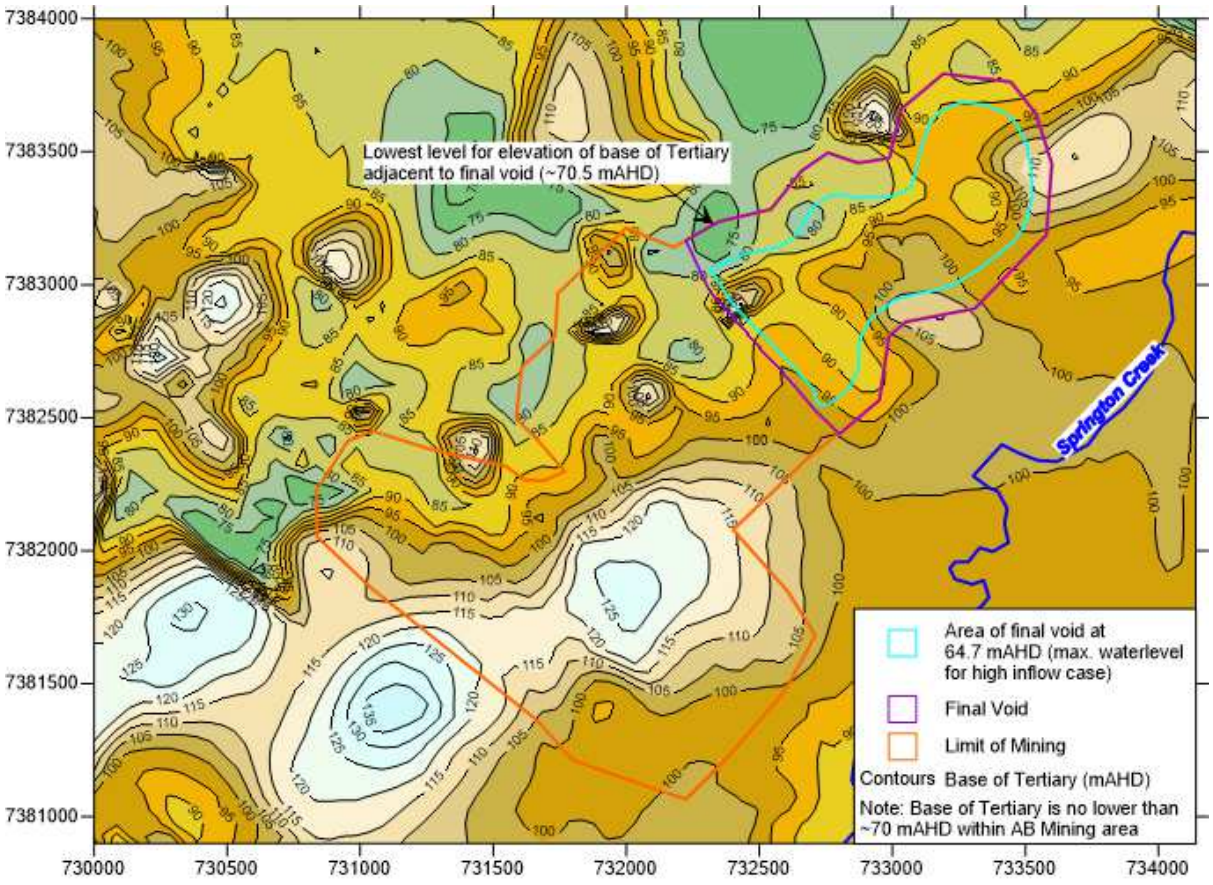

Figure 7-3: Base of Tertiary Contours and AB Pit Final Void Water Levels

- Assessment of the C Pit:
  - Figure 7-4 shows the base of Tertiary contours for the area around the C Pit and includes:
    - The limit of mining within the C Pit;
    - The location of the final void;
    - The area of the final void that is within the area of inundation at the maximum water level for the High Inflow Case of 80.0 mAHD;
    - The contour line for the base of Tertiary at the Base Case maximum water level of 73.6 mAHD;
    - The contour line for the base of Tertiary at the High Inflow Case maximum water level of 80.0 mAHD

- The location of the closest environmental receptor (Springton Creek), which occurs to the east of the C Pit.

- From the assessment it is concluded that:
  - The areas where the base of Tertiary is at or below the Base Case or High Inflow Case water levels in within the final void area, i.e. an area that will be removed by mining;
  - The lowest level for the base of Tertiary adjacent to the C Pit mining area and final void area is approximately 82.5 mAHD (as shown on Figure 7-4), which is approximately 2.5 m above the maximum water level for the High Inflow Case;
  - The elevation of the base of Tertiary increases away from the area described above to an elevation of approximately 88.5 mAHD, before the elevation of base of Tertiary reduces again towards Springton Creek
  - Therefore, there is no outlet for water within the final void of the C Pit via the base of Tertiary sediments

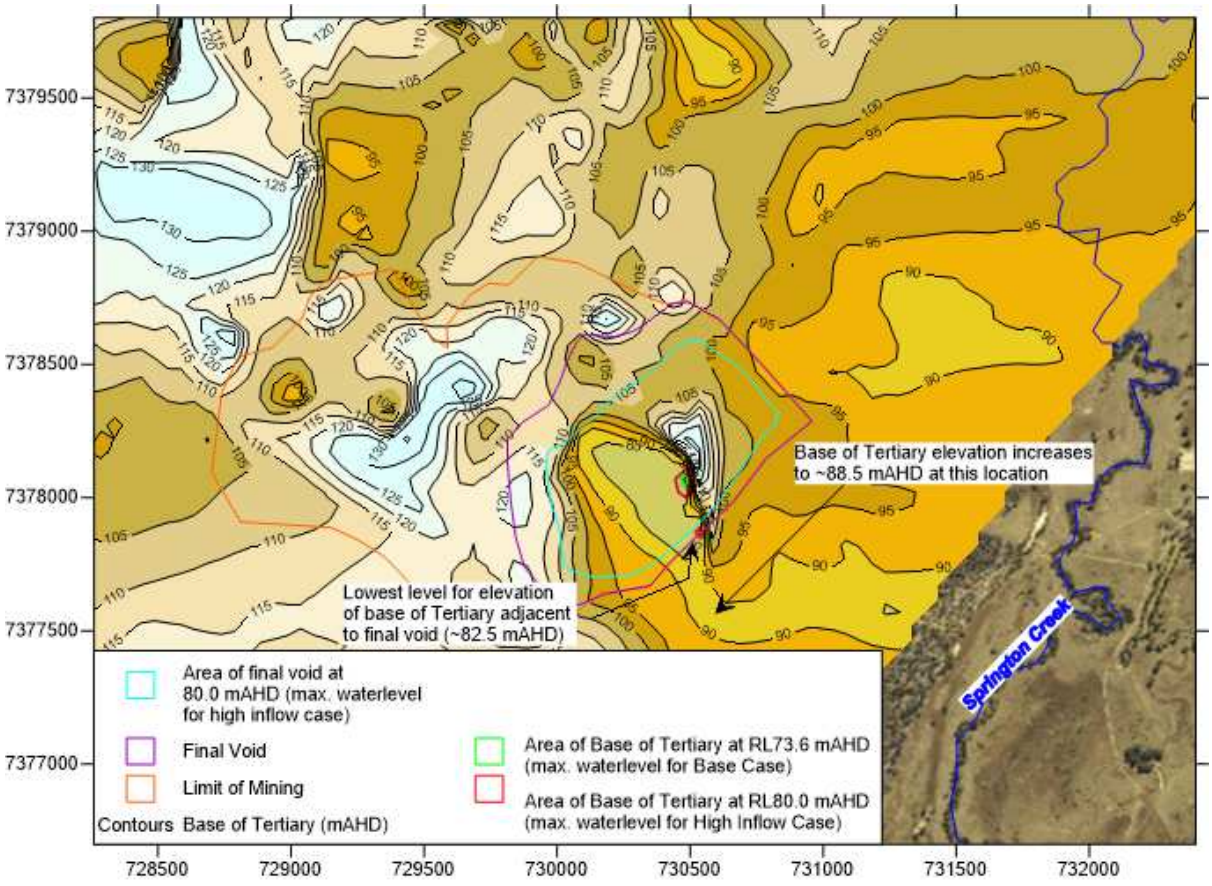

Figure 7-4: Base of Tertiary Contours and C Pit Final Void Water Levels

Based on the assessment undertaken above it is concluded that there is a very low risk of water within the final voids of the AB and C Pits impacting the surrounding groundwater system

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8.0 SUMMARY AND CONCUSIONS

8.1 Review of Project and Site Data

- The Gemini Project proposes to mine coal from the Aries, Castor and Pollux coal seams of the Rangal Coal Measures, at depths of up to 185 mbgl;
- The mined voids will be progressively backfilled with waste rock (spoil) and the final voids will be backfilled with spoil to approximately 80 mbgl; this backfilling is being undertaken to reduce groundwater seepage to the final void and to limit the impact of mining on groundwater levels;
- Groundwater occurs within three main groundwater units at site, including:
  - Quaternary alluvium associated with Charlevue Creek and Springton Creek
  - Tertiary sediments of the Duaringa Formation; and,
  - The Permian Rangal Coal Measures, where groundwater occurs preferentially within the coal seams
- The site is heavily faulted and the faults may act to influence groundwater occurrence and movement as follows:
  - Shear zones associated with faulting may act as a store of water and as locally higher hydraulic conductivity zones. As discussed below, recharge to the groundwater system is assessed to be low; therefore the faults may provide initial relatively high inflow rates to the workings (in the order of several L/s), but the total storage within the faults is anticipated to be relatively low, with the initial rates of inflow not able to be sustained in the long-term; and,
  - Where the faults completely disrupt the coal seams, especially for cases where the coal seam terminates against lower-hydraulic conductivity interburden, the faults will act to disrupt groundwater flow.
- Available hydraulic conductivity and air-lift yield data indicates that there is notable reduction in hydraulic conductivity and bore yield for bores that are deeper than 80 mbgl compared to bores that are shallower than 80 mbgl.
- Groundwater level data at site are summarised as:
  - The water level within the alluvium ranges from 8.77 to 11.19 m below ground level for bores adjacent to the creek channels;
  - The water level with the Tertiary sediments ranges from dry (5 bores, ranging in depth from 14 to 23 m) to 15.38-44.74 mbgl (where water is present). The presence of water within the Tertiary sediments is related to the RL of the base of Tertiary and from review of available data it is assessed that it is probable that the Tertiary sediments are dry above 120 mAHD and likely dry above 110 mAHD; and,
  - The water level in the coal measures ranges from 16.91 to 46.62 mbgl for bore depths of between 38.4 and 136.7 m, with one bore dry at a depth of 31.59 m. The groundwater flow direction for groundwater within the coal measures is from southwest to northeast and from northwest to southeast, towards a depression that is centred on the area where the AB Pit is proposed to be developed.
- Groundwater quality data is summarised as:
  - All groundwater units at site record high EC groundwater, as follows:
    - Alluvial sediments – EC data is available from:

- A bore adjacent to Charlevue Creek (DW7076W), where the recorded EC range is from 15,200 µS/cm to 16,600 µS/cm; and,
- A bore adjacent to Springton Creek (DW7292W1) has recorded an EC value of 5,948 µS/cm from a single field value (sampling of the recently-drilled monitoring bores commenced in September 2019 with no laboratory data available to date);

▪ Tertiary sediments - the EC ranges from 20,200 µS/cm to 21,900 µS/cm;

▪ Coal seams - the EC ranges from 22,100 µS/cm to 28,500 µS/cm.

- Groundwater at site is above the ANZECC 2000 freshwater ecosystem protection trigger value (95% species protection) for boron (all samples), zinc (majority of samples) as well as aluminium, arsenic, copper, lead and nickel (a number of samples for each analyte).
- All groundwater samples collected to data are assessed to represent the background water quality for the site.
- The recharge rate to the groundwater units at site, which has been calculated via the chloride mass balance method, indicates an extremely low recharge rate of less than 1 mm/year for each groundwater unit. The low rate of calculated recharge is consistent with the observation of highly saline groundwater at site, which is present for even the shallow alluvial units.
- The observation of a low recharge rate for groundwater suggests that, even though relatively high rates of groundwater inflow may be observed from faults/shear zones as mining progresses, especially for the zone above 80 mbgl, the inflow rates are likely to be of short duration due to the relatively low volume that can be stored within fractures/faults and the very low rates of recharge observed at site (i.e. once the fault storage is depleted the faults are unlikely to be recharged).
- Because the faults may act as conduits for groundwater movement, the control of surface water around the site will be of particular importance (i.e. water that ponds at surface may recharge the underlying sediments and report as seepage to the pits via movement along faults/fractures). This mode of inflow would represent infiltrated surface water rather than groundwater from the formations.

8.2 Groundwater Modelling

- 2-dimensional groundwater models have been developed within the program Seep/W for three locations, including
  - A west-east cross section through the C Pit;
  - A west-east cross section through the AB Pit; and,
  - A long section that runs through the final void of both the C Pit and the AB Pit.
- The models take into account:
  - the mining schedule (progression of mining, depth of mining);
  - the progressive backfilling of the pits with waste rock (spoil); and,
  - The backfilling of the final voids to a dept that corresponds to approximately 80 mbgl.
- The models have been utilised to provide the following output:
  - Inflow rates over time to the mine throughout the mining period and to the final void, including inflow rates from the natural groundwater units (Permian coal measures, Tertiary sediments) as well as the spoil aquifer. Groundwater inflow rates to the final voids took into account the partial backfilling of the voids with spoil and the average level of the final void lakes.

- The predicted extent of drawdown (2 m and 5 m drawdown contours) at end of mining and post-mining equilibrium (i.e. steady-state)

- Observations with respect to the calculated inflow rates are as follows:
  - The highest inflow rates to the AB Pit occur in mining years 11 and 12 and are due to groundwater from the spoil reporting to the final void area;
  - For the purpose of future associated water licence reporting it is concluded that it would be more reasonable to assume the rate of inflow prior to development of the spoil aquifer (i.e. ~5.7 L/s or ~500 m^3/day) as the water that is developed from the spoil is derived mainly from rainfall recharge to the spoil and does not represent water from the natural formation;
  - The modelled inflow rates and net inflow rates (i.e. modelled inflow less evaporation) reduces significantly in mining years 17 and 18 for the AB Pit and at mining year 18 for the C Pit. This is due to the partial backfilling of the final void area with spoil; and,
  - For the post-mining years the net groundwater inflow rate is zero, as the rate of inflow from the pit walls above the backfilled area of spoil and the final void lake occurs at such a low rate that the rate of evaporation is significantly greater than the modelled rate of inflow.

8.3 Groundwater Impacts from Mining

Observations with respect to potential groundwater impacts from mining include:

- Impacts on existing groundwater users:
  - There are a total of eleven registered groundwater bores (listed from the DNRM groundwater database as either existing or abandoned but useable) within the zone of 2 m drawdown at post-mining equilibrium.
  - A number of sites are either located within land that is owned by Magnetic South (the project proponent) or record an EC >10,000 µS/cm, making the groundwater quality of little or no beneficial use.
  - Two bores that record an EC <1,000 µS/cm are assessed to be in an elevated area that is potentially disconnected from the regional groundwater system that the mining project is developed within. At these sites it is also noted that the sites are not located within the zone of potential impact at end of mining, but are within the zone of potential impact at post-mining equilibrium.
  - Notwithstanding the time that it may take for drawdown impacts to be observed at the private groundwater bores, it is recommended that a bore survey be undertaken on the potentially impacted properties (as defined by the extent of 2 m drawdown contour on Figure 6-8).
  - It is further noted that make-good agreements may be required for groundwater bores within the zone of potential impact, in the event that groundwater level drawdown affects the utility of the bores.
- Impacts on groundwater dependent ecosystems:
  - A potential groundwater dependant ecosystem (GDE) has been mapped to the east of the MLA and is discussed in Section 7.2.1. The potential GDE is located on an elevated ridgeline but in an area where surface water drainage is internal towards the potential GDE. It is therefore interpreted that the vegetation at this location may be groundwater dependent, but that the site is perched above the regional groundwater system and may be maintained in the dry season by a shallow groundwater lens that is seasonally replenished by surface flow and localised recharge. It is therefore interpreted that, although the site is located within the 2 m zone of

drawdown impacts from mining, there is a low risk of impact due to the perched nature of the system and the assessment that the site is likely to be disconnected from the regional groundwater system.

- A number of potential GDE's in the Project area are riverine-type wetlands that include riparian vegetation on watercourses and floodplains. With respect to the potential for the mining operation to impact this type of potential GDE, it is concluded that:
  - Groundwater level drawdown from the proposed mining operation will extend beneath Charlevue Creek and Springton Creek and it cannot be ruled out that drawdown from mining may affect water levels in the alluvium at some locations;
  - The riparian vegetation at site (within both Charlevue Creek and Springton Creek) is likely to subsist on water that becomes available following wet-season flow events in the creeks, and on the soil moisture and/or perched groundwater that may exist for some time after flow events in the creek, rather than on the water table that exists at greater depth (in the range of 9 to 11 m, based on available data) where the water is moderately to highly saline (and in the case of data for the Charlevue Creek alluvium, too saline to be tolerated by the vegetation species that line the creek); and,
  - Therefore, even if mining does impact on groundwater levels within the alluvium, the risk of impacts to existing riparian vegetation is assessed to be very low, as it is assessed that it is unlikely that the vegetation is dependent on groundwater for survival.
- Notwithstanding the above assessment, ongoing monitoring of groundwater levels is recommended, with a recommendation that bores within the alluvium are monitored via water level dataloggers to allow assessment of the range of seasonal water level variation at these sites. It is noted that a data logger is already fitted to bore DW7076W and that it is planned to install a logger in bore DW7292W1.

- Cumulative Impacts
  - There are no mining operations within the zone of predicted drawdown from mining at the Gemini Project site; it is therefore concluded that there are no cumulative impacts to assess.
- Impacts on Groundwater Quality
  - Groundwater modelling undertaken for this report predicts that a permanent cone of depression will develop that will direct groundwater flow towards the final voids; therefore, the risk of the project impacting on water quality (via outflow to the groundwater system) is assessed to be low.
  - It is, however, assessed that the Project could impact groundwater quality if the water within the final void were able to exit the void via unconsolidated sediments (i.e. the base of Tertiary) and flow via the groundwater system towards sensitive environmental receptors such as Springton Creek. For this reason, an assessment of the potential for water within the final voids to exit the void via the base of Tertiary sediments has been undertaken as follows:
    - Contours for the base of Tertiary sediments was obtained for the area of the AB Pit and C Pit from the site geological model;
    - The final void water level was obtained for each of the final voids from the WRM surface water assessment report (WRM 2019) and was assessed for:
      - The maximum final void water level for the Base Case; and,
      - The maximum final void water level for the High Inflow Case.

- The data for each mining area was assessed to establish whether any pathways existed for water to exit the final void via the base of Tertiary sediments, for the maximum Base Case and maximum High Inflow Case final void water levels.

- Based on the assessment described above it is concluded that there is no outlet via the base of Tertiary for water within the final void of either the AB Pit or the C Pit, for either the maximum Base Case water level or the maximum High Inflow Case water level.
- It is therefore concluded that there is a low risk of the Project impacting on groundwater quality.

9.0 REFERENCES

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Reilly, T.E. & Harbaugh, A.W. (2004) *Guidelines for Evaluation Groundwater Flow Models*. United States Geological Survey, Scientific Investigations Report 2004-5038.

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APPENDIX A

BORE CONSTRUCTION LOGS

Project: Gemini Project

Bore ID: DW7033W1

Drilled Date: 30-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, light to medium greyish brown, sandy		0	124		Stickup to Lip of Steel Monument - 1.04 m
SAND, light creamy white, clayey with limonitic traces					
SAND, light creamy white, clayey		4	120		Grout from surface to 37 mbgl
CLAY, silty, light greyish-white, sandy		8	116		50 mm Class 18 PVC Environmental Casing
CLAY, silty, light to medium brownish-white, with ferruginous traces near base of unit		12	112		
FERRICRETE, dark reddish-brown		16	108		
CLAY, silty, lightish-white		20	104		
FERRICRETE, dark reddish-brown		24	100		
CLAY, silty, light white, ferruginous lenses near top of unit		28	96		Water level - 29.94 mbgl - 17/7/2019
SAND, clayey, light creamy-white, coarse					
CLAY, light to medium greyish-white, ferruginous lenses near middle of unit		32	92		
		36	88		Bentonite Seal - 37 to 38 mbgl
SAND, light to medium orangey grey, limonitic traces, base of Tertiary at 42.5 mbgl		40	84		Gravel Pack - 38 to 45 mbgl
SILTSTONE, light to medium orangey brown		44	80		Screen - machine-slotted 50 mm PVC - 39 to 45 mbgl
		48			

JBT consulting

Easting: 731543.2

Northing: 7383768

Collar RL (mAHD): 124.4

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 45.23

Project: Gemini Project

Bore ID: DW7033W2

Drilled Date: 29-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, light to medium greyish-brown, sandy		0	124		Stickup to Lip of Steel Monument - 1.01 m
Sand, light greyish-white, clayey		4	120		Grout from surface to 71 mbgl
Clay, silty, light to medium brownish white, ferruginous traces near base of unit		8	116		50 mm Class 18 PVC Environmental Casing
		12	112		
		16	108		
FERRICRETE, dark reddish-brown					
Clay, silty, lightish white		20	104		
FERRICRETE, dark reddish-brown					
CLAY, silty, lightish-white, ferruginous lenses near top of unit		24	100		
		28	96		Water level - 29.01 mbgl - 17/7/2019
SAND, clayey, light creamy white					
CLAY, lightish white		32	92		
SAND, light to medium greyish-white, clayey		36	88		
CLAY, light to medium greyish-white, limonitic traces, base of Tertiary at 42.5 mbgl		40	84		
SILTSTONE, medium to dark orangey-brown		44	80		
		48	76		
		52	72		
SANDSTONE, fine to medium, light to medium grey					
COAL, Orion 4 Seam, fresh		56	68		
SILTSTONE, medium grey, minor sandstone					
SANDSTONE, fine to medium, light to medium grey, common siltstone fragments		60	64		
SANDSTONE, fine to coarse, light to medium grey					
		64	60		
SILTSTONE, dark grey		68	56		
		72	52		Bentonite Seal - 71 to 72 mbgl Gravel Pack - 72 to 74.5 mbgl Screen - machine-slotted 50 mm PVC - 73 to 74.5 mbgl
COAL, Orion 5 Seam, fresh					
		76	48		
		80			

JBT consulting

Easting: 731546.2

Northing: 7383773.1

Collar RL (mAHD): 124.45

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 74.77

Project: Gemini Project

Bore ID: DW7033W3

Drilled Date: 28-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, light to medium greyish-brown, sandy		0	125		Stickup to Lip of Steel Monument - 1.04 m
SAND, light greyish-white, clayey		5	120		Grout from surface to 77.5 mbgl
CLAY, silty, light to medium brownish white, ferruginous traces near base of unit		10	115		50 mm Class 18 PVC Environmental Casing
		15	110		
FERRICRETE, dark reddish-brown CLAY, silty, lightish white		20	105		
FERRICRETE, dark reddish-brown CLAY, silty, lightish-white, ferruginous lenses near top of unit		25	100		
SAND, clayey, light creamy white		30	95		Water level - 28.93 mbgl - 17/7/2019
CLAY, lightish white		35	90		
SAND, light to medium greyish-white, clayey		40	85		
CLAY, light to medium greyish-white, limonitic traces, base of Tertiary at 42.5 mbgl		45	80		
SILTSTONE, medium to dark orangey-brown		50	75		
SANDSTONE, fine to medium, light to medium grey COAL, Orion 4 Seam, fresh		55	70		
SILTSTONE, medium grey, minor sandstone		60	65		
SANDSTONE, fine to medium, light to medium grey, common siltstone fragments SANDSTONE, fine to coarse, light to medium grey		65	60		
SILTSTONE, dark grey		70	55		
COAL, Orion 5 Seam, fresh		75	50		
CARBONACEOUS SILTSTONE, black		80	45		
SILTSTONE, medium grey, abundant sandstone near base of unit					Bentonite Seal - 77.5 to 78.5 mbgl Gravel Pack - 78.5 to 81.0 mbgl Screen - machine-slotted 50 mm PVC - 79.5 to 81.0 mbgl

JBT consulting

Easting: 731548.4

Northing: 7383777.5

Collar RL (mAHD): 124.43

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 81

Project: Gemini Project

Bore ID: DW7035W3

Drilled Date: 31-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, dark brown, clayey and silty		0	116		Stickup to Lip of Steel Monument - 1.06 m
CLAY, dark reddish-brown, silty, sandy near base of unit					
SAND, medium to dark reddish-brown		4	112		
		8	108		Grout from surface to 44.9 mbgl
SAND, medium brownish-red		12	104		
IRONSTONE, medium to dark reddish-brown					
SAND, medium brownish-red					
FERRICRETE, dark reddish-brown					
GRAVEL, medium to dark brownish grey, sandy with ferruginous grains		16	100		50 mm Class 18 PVC Environmental Casing
SAND, medium brownish-red					
CLAY, light to medium brownish-white, sandy near base of unit		20	96		Water level - 21.75 mbgl - 16/7/2019
SAND, silty, light greyish-white		24	92		
CLAY, sandy, light yellowish-brown, base of Tertiary at 33 mbgl		28	88		
		32	84		
SILTSTONE, medium to dark orangey-brown, clayey					
LIMONITE, medium to dark reddish-brown, ferruginous					
SILTSTONE, light to medium brownish-grey		36	80		
SILTSTONE, medium to dark greyish0brown					
SANDSTONE, light to medium brownish-grey		40	76		
SILTSTONE, medium grey, sandstone near base of unit		44	72		Bentonite Seal - 44.9 to 45.9mbgl Gravel Pack - 45.9 to 48.4 mbgl
COAL, Orion 1 seam, black, fresh		48	68		
SANDSTONE, fine-grained, medium grey					Screen - machine-slotted 50 mm PVC - 46.9 to 48.4 mbgl
		52			

JBT consulting

Easting: 730957.4

Northing: 7384050

Collar RL (mAHD): 116.67

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 48.47

Project: Gemini Project

Bore ID: DW7065W

Drilled Date: 05-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL: medium to dark grey, loose, earthy		0	136		Stickup to Lip of Steel Monument - 1.0 m
CLAY: light brownish-white, firm, chalky.		4	132		
CLAY, sandy : light orangey-white, with ferruginous traces, firm, chalky, haematitic.		8	128		
SAND: light yellowish-white, loose.		12	124		
CLAY: light white, sandy ferruginous bands near middle of unit, stiff, chalky, haematitic		16	120		
SAND, clayey: light greyish-white, very clayey, medium dense.		20	116		Grout from surface to 69.3 mbgl
GRAVEL, clayey: medium to dark reddish-brown, very clayey, dense.		24	112		
CLAY: light brown, sandy, stiff.		28	108		
CLAY, silty : medium to dark orangey-brown, stiff, chalky, haematitic.		32	104		
Base of Tertiary at 54 mbgl.		36	100		
SILTSTONE : medium to dark reddish-brown, clayey, weathered.		40	96		50 mm Class 18 PVC Environmental Casing
Base of Weathering at 61.5 mbgl		44	92		
SILTSTONE : medium to dark grey.		48	88		Water level - 47.30 mbgl - 26/8/2019
SILTSTONE : black, fresh.		52	84		
COAL: black, fresh, Aries 3 Upper Seam		56	80		
SILTSTONE : medium to dark grey, fresh.		60	76		
COAL: black, fresh, Aries 3 Seam.		64	72		
SILTSTONE : medium to dark grey.		68	68		Bentonite Seal - 69.3 to 70.3 mbgl
COAL: black, Aries 3 Lower Seam.		72	64		Gravel Pack - 70.3 to 77.3 mbgl
SILTSTONE : medium to dark grey.		76	60		Screen - machine-slotted 50 mm PVC - 71.3 to 77.3 mbgl
		80	56		

JBT consulting

Easting: 730860.4

Northing: 7382307.1

Collar RL (mAHD): 135.97

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 77.27

Project: Gemini Project

Bore ID: DW7066W

Drilled Date: 05-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
		1	137		Stickup to Lip of Steel Monument - 0.94 m
SOIL: medium to dark grey, loose, earthy.		0	136		
		1	135		Grout from surface to 9.35 mbgl
		2	134		
		3	133		
		4	132		
CLAY : light brownish-white, firm, chalky.		5	131		50 mm Class 18 PVC Environmental Casing
		6	130		
		7	129		
		8	128		
		9	127		
		10	126		
CLAY, sandy : light yellowish-white, with limonitic traces, firm, chalky, haematitic.		11	125		Bentonite Seal - 9.35 to 10.35 mbgl
		12	124		
		13	123		
		14	122		
		15	121		Gravel Pack - 10.35 to 17.35 mbgl
SAND: light white, loose.		16	120		
		17	119		Screen - machine-slotted 50 mm PVC - 11.35 to 17.35 mbgl
		18	118		
		19			Bore Dry - 26/8/2019

JBT consulting

Easting: 730863.1

Northing: 7382304.1

Collar RL (mAHD): 136.37

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

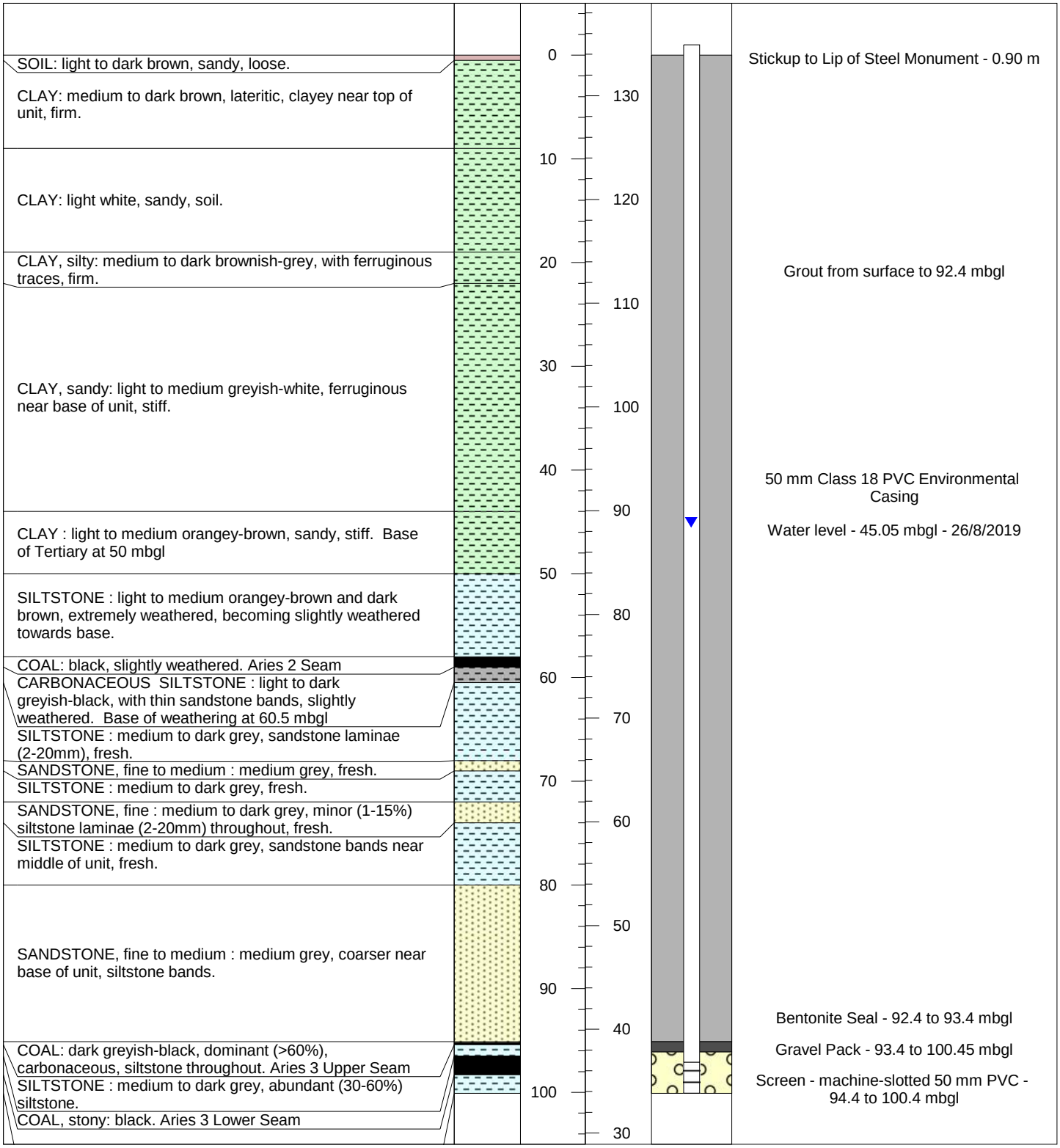
Total Depth (m): 17.35

Project: Gemini Project

Bore ID: DW7067W

Drilled Date: 06-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes



Easting: 730781.2	Drilling Company: Hodge Drilling
Northing: 7382393.8	Drill Rig: Gardner Denver 1400
Collar RL (mAHD): 133.92	Hole Diameter (mm): 120
Co-ord System: GDA94	Total Depth (m): 100.14

Project: Gemini Project

Bore ID: DW7068W

Drilled Date: 06-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL: light to dark brown, sandy, loose.		0	134		Stickup to Lip of Steel Monument - 0.94 m
CLAY: medium to dark greyish-brown, lateritic and clayey near top of unit, firm.		4	132		
CLAY: light brownish-white, firm.		8	128		
SAND: light white, clayey, dense		12	124		Grout from surface to 41 mbgl
CLAY: light greyish-white, sandy with ferruginous traces.		20	120		50 mm Class 18 PVC Environmental Casing
CLAY: light white, sandy, firm.		28	112		
CLAY, sandy: light to medium brownish-grey, ferruginous near base of unit, stiff.		36	104		
CLAY, sandy: light to medium reddish-brown, sandy, stiff.		40	96		Bentonite Seal - 41 to 42 mbgl Gravel Pack - 42 to 47.5 mbgl Screen - machine-slotted 50 mm PVC - 43 to 47.5 mbgl
SAND, clayey: light to medium greyish-white, with ferruginous traces, dense.		44	92		
		48	88		Water level - 45.68 mbgl - 26/8/2019

JBT consulting

Easting: 730785.4

Northing: 7382391.3

Collar RL (mAHD): 134

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 47.5

Project: Gemini Project

Bore ID: DW7069W

Drilled Date: 07-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL: light to dark brown, sandy, loose.		0	132		Stickup to Lip of Steel Monument - 0.95 m
CLAY : light to medium brown, silty and laminae (2-20mm), firm, finer near top of unit. Base of Tertiary at 16 mbgl.		4 8 12	128 124 120		
SILTSTONE : light to medium orangey-brown, with clayey bands, extremely weathered.		16 20	116 112		Grout from surface to 63.4 mbgl
SILTSTONE : medium to dark grey, slightly weathered.		24 28	108 104		
COAL, weathered : black, slightly weathered. Aries 3 Upper Seam		28	104		
SILTSTONE : grey, slightly weathered, very low strength rock		32	100		50 mm Class 18 PVC Environmental Casing
COAL, weathered : black, slightly weathered. Aries 3 Seam		32	100		
CARBONACEOUS SILTSTONE: light to dark greyish-black, with siltstone bands, slightly weathered, very low strength rock		36	96		
COAL, weathered: black, Aries 3 Lower Seam		40	92		
SILTSTONE: medium to dark grey, thin sandstone laminae (2-20mm) near base of unit, fresh		40 44	92 88		Water level - 42.73 mbgl - 26/8/2019
SANDSTONE, medium: light to medium grey, fresh		48	84		
SILTSTONE: medium to dark grey, fresh		48 52	84 80		
COAL: black, fresh. Castor Upper Seam		56	76		
SANDSTONE, fine to medium: light to medium grey, with common (15-30%) siltstone bands, fresh		56 60	76 72		
SILTSTONE: medium to dark grey, fresh		64	68		Bentonite Seal - 63.4 to 64.4 mbgl
COAL: black, fresh. Castor Lower Seam.		64	68		Gravel Pack - 64.4 to 71.4 mbgl
SILTSTONE: medium to dark grey, carbonaceous in part, fresh		68	64		
COAL: black, fresh. Pollux Upper Seam		68	64		Screen - machine-slotted 50 mm PVC - 65.4 to 71.4 mbgl
SILTSTONE: medium to dark grey, fresh		72	60		
COAL: black, thin siltstone bands near base of unit, fresh. Pollux Upper 1 Seam		72 76	60		

JBT consulting

Easting: 730397.1

Northing: 7382699

Collar RL (mAHD): 132.57

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 71.38

Project: Gemini Project

Bore ID: DW7071W

Drilled Date: 08-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL: light to medium reddish-brown, very loose		0	132		Stickup to Lip of Steel Monument - 0.97 m
CLAY : light to medium brown, silty and laminae (2-20mm)		2	130		
CLAY : light white, ferruginous, granules traces near top of unit, firm		4	128		Grout from surface to 26.6 mbgl
		6	126		
		8	124		
		10	122		50 mm Class 18 PVC Environmental Casing
CLAY, sandy : light to medium reddish-brown, ferruginous, firm, haematitic. Base of Tertiary at 18 mbgl.		12	120		
		14	118		
		16	116		
		18	114		
SILTSTONE : light to medium greyish-brown, clayey, extremely weathered		20	112		
		22	110		
		24	108		Bore Dry - 26/8/2019
		26	106		Bentonite Seal - 26.6 to 27.6 mbgl
		28	104		Gravel Pack - 27.6 to 31.6 mbgl
COAL: black, extremely weathered. Aries 3 Upper Seam		30	102		Screen - machine-slotted 50 mm PVC - 28.6 to 31.6 mbgl
SILTSTONE : medium to dark greyish-grey, extremely weathered.					
COAL: extremely weathered. Aries 3 Seam					
SILTSTONE : medium to dark brownish-grey, soil and clayey, slightly weathered.		32			

JBT consulting

Easting: 730394.4

Northing: 7382702.7

Collar RL (mAHD): 132.4

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 31.59

Project: Gemini Project

Bore ID: DW7072W

Drilled Date: 08-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
		1	133		Stickup to Lip of Steel Monument - 0.93 m
SOIL: light to medium reddish-brown, very loose.		0	132		
CLAY: light to medium brown, silty		1	131		Grout from surface to 9 mbgl
		2	130		
		3	129		
		4	128		
CLAY: light greyish-white, lateritic		5	127		50 mm Class 18 PVC Environmental Casing
		6	126		
		7	125		
		8	124		
CLAY, silty: light white		9	123		Bentonite Seal - 9 to 10 mbgl
		10	122		
		11	121		Gravel Pack - 10 to 14 mbgl
CLAY, silty: light creamy-white, rare (<1%) ferruginous traces, firm.		12	120		
		13	119		Screen - machine-slotted 50 mm PVC - 11 to 14 mbgl
CLAY: medium to dark reddish-brown, ferruginous with limonitic traces, firm, haematitic. Base of Tertiary at 14 mbgl		14			Bore Dry - 26/8/2019

JBT consulting

Easting: 730403.1

Northing: 7382686.8

Collar RL (mAHD): 132.3

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 14.01

Project: Gemini Project

Bore ID: DW7073W

Drilled Date: 11-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL: light brownish-red, lithic, oxidised, medium dense, earthy, haematitic		0	125		Stickup to Lip of Steel Monument - 0.90 m
SAND, clayey: light brownish-red, oxidised, ferruginous, firm, haematitic		5	120		
SAND, clayey: light creamy-white, firm, chalky		10	115		
CLAY: light greyish-white, firm, light reddish-brown and ferruginous towards base of unit. Base of Tertiary at 16 mbgl.		15	110		
SILTSTONE: light to medium greyish-brown, clayey bands near base of unit, extremely weathered,		20	105		Grout from surface to 77.1 mbgl
SILTSTONE: medium to dark greyish-brown, carbonaceous, extremely weathered		25	100		
SILTSTONE: medium to dark grey, oxidised, ferruginous in part, slightly weathered, haematitic. Base of weathering at 35 mbgl		30	95		
SILTSTONE: medium to dark grey, shaly near base of unit, fresh.		35	90		Water level - 32.71 mbgl - 26/8/2019
COAL: black, fresh, Aries Seam. Ground water observed by the driller.		40	85		
SILTSTONE: medium to dark grey, claystone bands near top of unit, fresh		45	80		50 mm Class 18 PVC Environmental Casing
COAL: black, fresh, Castor Upper Seam		50	75		
SILTSTONE: light to dark grey, carbonaceous, fresh, low strength rock, common (15-30%) plant fragments		55	70		
SANDSTONE, fine to medium: light to medium grey, with siltstone laminae (2-20mm)		60	65		
SILTSTONE: medium to dark grey		65	60		
COAL: black, Castor Lower Seam		70	55		
SILTSTONE: medium to dark grey.		75	50		
COAL: black, Pollux Upper Seam		80	45		Bentonite Seal - 77.1 to 78.1 mbgl
SILTSTONE: medium to dark grey		85	40		Gravel Pack - 78.1 to 82.1 mbgl
COAL: black, Pollux Upper 1 Seam			35		Screen - machine-slotted 50 mm PVC - 79.1 to 82.1 mbgl
SILTSTONE: medium to dark grey					

JBT consulting

Easting: 729925.9

Northing: 7382666

Collar RL (mAHD): 122.09

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 82.1

Project: Gemini Project

Bore ID: DW7074W

Drilled Date: 11-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL: light brownish-red, lithic, oxidised, medium dense, earthy, haematitic		0	124		Stickup to Lip of Steel Monument - 0.91 m
SAND, clayey: light brownish-red, oxidised, ferruginous, firm, haematitic.					
SAND, clayey: light creamy-white, firm, chalky		4	120		
CLAY: light greyish-white, firm, chalky			116		
CLAY: mottled yellowish-brown, firm		8			Grout from surface to 52.3 mbgl
CLAY: light reddish-white, oxidised, ferruginous near middle of unit. Base of Tertiary at 16 mbgl.		12	112		
SILTSTONE: light to medium greyish-brown, clayey bands near base of unit, extremely weathered		16	108		50 mm Class 18 PVC Environmental Casing
SILTSTONE: medium to dark reddish-brown, extremely weathered		20	104		
SILTSTONE: medium to dark grey, oxidised, ferruginous in part, slightly weathered. Base of Weathering at 35 mbgl		24	100		
SILTSTONE: medium to dark grey, shaly near base of unit		28	96		
COAL: black, Aries 3 Seam		32	92		Water level - 32.72 mbgl - 26/8/2019
SILTSTONE: medium to dark grey		36	88		
COAL: black, Aries 3 Lower Seam		40	84		
SILTSTONE: medium to dark grey		44	80		
COAL: black, Castor Upper Seam		48	76		
SILTSTONE: light to dark grey, carbonaceous, fresh, low strength rock, common (15-30%) plant fragments		52	72		Bentonite Seal - 52.3 to 53.3 mbgl Gravel Pack - 53.3 to 55.8 mbgl Screen - machine-slotted 50 mm PVC - 54.3 to 55.8 mbgl
		56	68		
		60	64		

JBT consulting

Easting: 729921.7

Northing: 7382665.9

Collar RL (mAHD): 122.04

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 55.78

Project: Gemini Project

Bore ID: DW7075W

Drilled Date: 11-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
		1	122		Stickup to Lip of Steel Monument - 1.09 m
SOIL: light brownish-red, lithic, oxidised, medium dense, earthy, haematitic		0			
SAND, clayey: light brownish-red, oxidised, ferruginous, firm, haematitic		1	121		
SAND, clayey: light creamy-white, firm, chalky		2	120		Grout from surface to 9 mbgl
		3	119		
		4	118		
		5	117		50 mm Class 18 PVC Environmental Casing
CLAY: light greyish-white, firm, chalky		6	116		
		7	115		
CLAY: mottled yellowish-brown, limonitic traces near top of unit, firm.		8	114		
		9	113		Bentonite Seal - 9 to 10 mbgl
CLAY: medium to dark greyish-brown, oxidised, ferruginous, firm, haematitic		10	112		
		11	111		Gravel Pack - 10 to 14 mbgl
		12	110		
CLAY: light greyish-white, minor (1-15%) limonitic traces, firm.		13	109		Screen - machine-slotted 50 mm PVC - 11 to 14 mbgl
		14	108		Bore Dry - 26/8/2019
		15	107		

JBT consulting

Easting: 729917.9

Northing: 7382665.7

Collar RL (mAHD): 121.83

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 14.03

Project: Gemini Project

Bore ID: DW7076W

Drilled Date: 12-Apr-2018

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
		1	120		Stickup to Lip of Steel Monument - 1.14 m
SOIL: medium to dark brown, loose.		0			
		1	119		
		2	118		Grout from surface to 7 mbgl
		3	117		
SAND: medium to dark reddish-brown, clayey near top of unit near base of unit, medium dense.		4	116		
		5	115		50 mm Class 18 PVC Environmental Casing
		6	114		
		7	113		Bentonite Seal - 7 to 8 mbgl
CLAY: light to medium whitish-grey, ferruginous, granules throughout, firm.		8	112		
		9	111		
CLAY, sandy: light to medium white, minor (1-15%) limonitic traces, stiff.		10	110		Water level - 9.78 mbgl - 26/8/2019 Gravel Pack - 8 to 12 mbgl
		11	109		Screen - machine-slotted 50 mm PVC - 9 to 12 mbgl
		12	108		

JBT consulting

Easting: 729749.5

Northing: 7382722.8

Collar RL (mAHD): 119.81

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig: Gardner Denver 1400

Hole Diameter (mm): 120

Total Depth (m): 12

Project: Gemini Project

Bore ID: DW7082W1

Drilled Date: 16-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, dark brownish-grey		0	136		Stickup to Lip of Steel Monument - 1.08 m
CLAY, silty, medium to dark		4	132		
SAND		8	128		
CLAY, sandy, medium greyish-brown		12	124		Grout from surface to 37 mbgl
CLAY, light to medium brownish-grey, sandy		16	120		Water level - 16.91 mbgl - 22/8/2019
		20	116		50 mm Class 18 PVC Environmental Casing
SILTSTONE, light to medium brownish-grey, sandy towards base of unit		24	112		
		28	108		
		32	104		
		36	100		Bentonite Seal - 37 to 38 mbgl
COAL, Castor Lower Seam		40	96		Gravel Pack - 38 to 40.6 mbgl Screen - machine-slotted 50 mm PVC - 39 to 40.5 mbgl

JBT consulting

Easting: 728989.3

Northing: 7378745.8

Collar RL (mAHD): 135.26

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 40.58

Project: Gemini Project

Bore ID: DW7082W2

Drilled Date: 16-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, dark brownish-grey		0	136		Stickup to Lip of Steel Monument - 0.99 m
CLAY, silty, medium to dark		4	132		
SAND		8	128		
CLAY, sandy, medium greyish-brown		12	124		Grout from surface to 55.7 mbgl
CLAY, light to medium brownish-grey, sandy		16	120		Water level - 17.04 mbgl - 22/8/2019
		20	116		50 mm Class 18 PVC Environmental Casing
SILTSTONE, light to medium brownish-grey, sandy towards base of unit		24	112		
		28	108		
		32	104		
		36	100		
COAL, Castor Lower Seam		40	96		
SILTSTONE		44	92		
CARBONACEOUS MUDSTONE, black		48	88		
SILTSTONE					
COALY SHALE, black					
CARBONACEOUS SILTSTONE, black					
SANDSTONE, fine to medium grained, light to medium grey					
SILTSTONE, light to dark grey		52	84		
SANDSTONE, light to medium grey					
SILTSTONE, sandstone bands					
SANDSTONE, fine to medium grained, grey		56	80		Bentonite Seal - 55.7 to 56.7 mbgl
SILTSTONE, light to dark grey					Gravel Pack - 56.7 to 59.2 mbgl
COAL, Pisces Upper Seam		60	76		Screen - machine-slotted 50 mm PVC - 57.7 to 59.2 mbgl
SILTSTONE, light to dark grey					
		64	72		

JBT consulting

Easting: 728986.3

Northing: 7378742.2

Collar RL (mAHD): 135.33

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

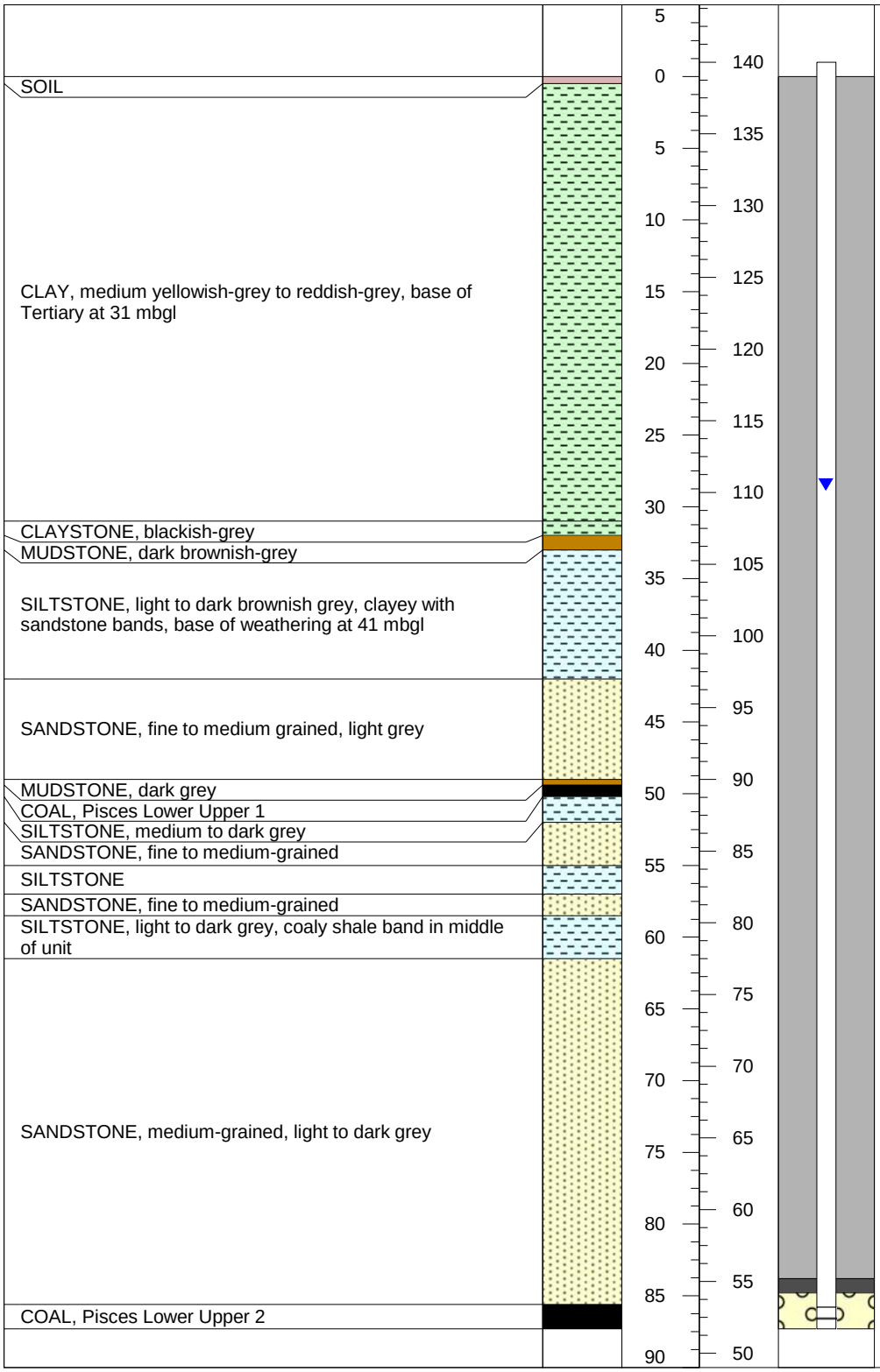
Total Depth (m): 59.17

Project: Gemini Project

Bore ID: DW7093W1

Drilled Date: 13-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL					Stickup to Lip of Steel Monument - 1.14 m
CLAY, medium yellowish-grey to reddish-grey, base of Tertiary at 31 mbgl					Grout from surface to 83.8 mbgl
					50 mm Class 18 PVC Environmental Casing
					Water level - 28.44 mbgl - 2/9/2019
CLAYSTONE, blackish-grey					
MUDSTONE, dark brownish-grey					
SILTSTONE, light to dark brownish grey, clayey with sandstone bands, base of weathering at 41 mbgl					
SANDSTONE, fine to medium grained, light grey					
MUDSTONE, dark grey					
COAL, Pisces Lower Upper 1					
SILTSTONE, medium to dark grey					
SANDSTONE, fine to medium-grained					
SILTSTONE					
SANDSTONE, fine to medium-grained					
SILTSTONE, light to dark grey, coaly shale band in middle of unit					
SANDSTONE, medium-grained, light to dark grey					
COAL, Pisces Lower Upper 2					Bentonite Seal - 83.8 to 84.8 mbgl Gravel Pack - 84.8 to 87.3 mbgl Screen - machine-slotted 50 mm PVC - 85.8 to 87.3 mbgl



JBT consulting

Easting: 730095.9

Northing: 7378973.6

Collar RL (mAHD): 139

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 87.3

Project: Gemini Project

Bore ID: DW7093W2

Drilled Date: 12-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL		0	140		Stickup to Lip of Steel Monument - 1.14 m
CLAY, medium yellowish-grey to reddish-grey, base of Tertiary at 31 mbgl		10	130		Grout from surface to 95.7 mbgl
		20	120		50 mm Class 18 PVC Environmental Casing
		30	110		Water level - 28.45 mbgl - 2/9/2019
CLAYSTONE, blackish-grey					
MUDSTONE, dark brownish-grey					
SILTSTONE, light to dark brownish grey, clayey with sandstone bands, base of weathering at 41 mbgl		40	100		
SANDSTONE, fine to medium grained, light grey					
MUDSTONE, dark grey		50	90		
COAL, Pisces Lower Upper 1					
SILTSTONE, medium to dark grey					
SANDSTONE, fine to medium-grained					
SILTSTONE					
SANDSTONE, fine to medium-grained					
SILTSTONE, light to dark grey, coaly shale band in middle of unit		60	80		
SANDSTONE, medium-grained, light to dark grey		70	70		
		80	60		
COAL, Pisces Lower Upper 2					
SILTSTONE, light to dark grey					
SANDSTONE, medium-grained		90	50		
SILTSTONE, light to dark grey					
		100	40		Bentonite Seal - 95.7 to 96.7 mbgl Gravel Pack - 96.7 to 99.2 mbgl Screen - machine-slotted 50 mm PVC - 97.7 to 99.2 mbgl

JBT consulting

Easting: 730095.9

Northing: 7378973.6

Collar RL (mAHD): 139

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 87.3

Project: Gemini Project

Bore ID: DW7093W3

Drilled Date: 11-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL		0	140		Stickup to Lip of Steel Monument - 1.05 m
CLAY, medium yellowish-grey to reddish-grey, base of Tertiary at 31 mbgl		10	130		Grout from surface to 119.8 mbgl
		20	120		50 mm Class 18 PVC Environmental Casing
		30	110		Water level - 28.46 mbgl - 2/9/2019
CLAYSTONE, blackish-grey					
MUDSTONE, dark brownish-grey					
SILTSTONE, light to dark brownish grey, clayey with sandstone bands, base of weathering at 41 mbgl		40	100		
SANDSTONE, fine to medium grained, light grey		50	90		
MUDSTONE, dark grey					
COAL, Pisces Lower Upper 1					
SILTSTONE, medium to dark grey					
SANDSTONE, fine to medium-grained		60	80		
SILTSTONE					
SANDSTONE, fine to medium-grained					
SILTSTONE, light to dark grey, coaly shale band in middle of unit		70	70		
SANDSTONE, medium-grained, light to dark grey		80	60		
COAL, Pisces Lower Upper 2					
SILTSTONE, light to dark grey		90	50		
SANDSTONE, medium-grained					
SILTSTONE, light to dark grey		100	40		
SANDSTONE, fine-grained					
SILTSTONE, light to dark grey		110	30		
COAL, Pisces Lower Lower 1					
SILTSTONE, light to dark grey		120	20		Bentonite Seal - 119.8 to 120.8 mbgl Gravel Pack - 120.8 to 123.3 mbgl Screen - machine-slotted 50 mm PVC - 121.8 to 123.3 mbgl
COAL, Pisces Lower Lower 2		130	10		

JBT consulting

Easting: 730088

Northing: 7378973.6

Collar RL (mAHD): 139.12

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 123.25

Project: Gemini Project

Bore ID: DW7105W1

Drilled Date: 17-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
		2	130		Stickup to Lip of Steel Monument - 0.95 m
SOIL, medium to dark brown		0	128		
CLAY, medium to dark brown		2	126		
		4	124		Grout from surface to 18 mbgl
BASALT, medium to dark yellowish brown, highly weathered		6	122		
		8	120		
		10	118		50 mm Class 18 PVC Environmental Casing
		12	116		
		14	114		
BASALT, medium to dark orangey grey, common ferruginous lenses		16	112		Water level - DRY - 25/7/2018
		18	110		Bentonite Seal - 18 to 19 mbgl
BASALT, sandy beneath base of unit, base of Tertiary at 23 mbgl		20	108		Gravel Pack - 19 to 23 mbgl
		22	106		Screen - machine-slotted 50 mm PVC - 20 to 23 mbgl
		24			

JBT consulting

Easting: 730192.1

Northing: 7380733

Collar RL (mAHD): 128.67

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 23.04

Project: Gemini Project

Bore ID: DW7105W2

Drilled Date: 16-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown		0	128		Stickup to Lip of Steel Monument - 1.02 m
CLAY, medium to dark brown		4	124		
BASALT, medium to dark yellowish brown, highly weathered		8	120		Grout from surface to 60.7 mbgl
BASALT, medium to dark orangey grey, common ferruginous lenses		12	116		
BASALT, sandy beneath base of unit, base of Tertiary at 23 mbgl		16	112		
SILTSTONE, medium to dark brown and orangey-brown		20	108		50 mm Class 18 PVC Environmental Casing
COAL, Pisces Upper Seam		24	104		
SANDSTONE, fine-grained, light to dark grey to black		28	100		
CARBONACEOUS SILTSTONE		32	96		Water level - 31.08 mbgl - 22/8/2019
COALY SHALE		36	92		
SILTSTONE		40	88		
COALY SHALE		44	84		
SANDSTONE, fine-grained, light to dark grey		48	80		
CARBONACEOUS SILTSTONE		52	76		
SANDSTONE, fine to medium-grained, medium to dark grey		56	72		
CARBONACEOUS SILTSTONE		60	68		Bentonite Seal - 60.7 to 61.7 mbgl
SANDSTONE, grey					Gravel Pack - 61.7 to 64.2 mbgl
SILTSTONE, light to dark grey		64	64		Screen - machine-slotted 50 mm PVC - 62.7 to 64.2 mbgl
COAL, Pisces Lower Upper 1 Seam		68	60		Bentonite seal in overdrilled zone below casing
SILTSTONE, grey		72			
COAL, Pisces Lower Upper 1 Seam					
SILTSTONE, light to dark grey					

Easting: 730193	Drilling Company: Hodge Drilling
Northing: 7380729	Drill Rig:
Collar RL (mAHD): 128.7	Hole Diameter (mm): 120
Co-ord System: GDA94	Total Depth (m): 69.25

Project: Gemini Project

Bore ID: DW7178W1

Drilled Date: 24-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown		0	128		Stickup to Lip of Steel Monument - 0.97 m
CLAY					
CLAY, lateritic		4	124		
FERRICRETE, dark reddish-brown					
CLAY		8	120		
SAND, fine-grained, light to medium yellow					
CLAY, sandy, light to medium whitish-cream		12	116		Grout from surface to 42 mbgl
CLAY, lateritic		16	112		
		20	108		50 mm Class 18 PVC Environmental Casing
FERRICRETE, dark reddish-brown					
CLAY, ferruginous traces		24	104		
CLAY, sandy, light to medium whitish-cream		28	100		
		32	96		
CLAY, light to medium pinkish cream, lateritic		36	92		Water level - 37.17 mbgl - 16/7/2019
		40	88		Bentonite Seal - 42 to 43 mbgl
SAND, fine to medium-grained, orangey-cream		44	84		Gravel Pack - 43 to 48.5 mbgl
GRAVEL, sandy, base of Tertiary at 47.5 mbgl					Screen - machine-slotted 50 mm PVC - 44 to 48.5 mbgl
SILTSTONE, medium to dark orangey-brown		48	80		Bentonite seal in overdrilled zone below casing
		52			

JBT consulting

Easting: 732173.7

Northing: 7383260

Collar RL (mAHD): 128.65

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 51.15

Project: Gemini Project

Bore ID: DW7178W2

Drilled Date: 24-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown		0	128		Stickup to Lip of Steel Monument - 1.02 m
CLAY					
CLAY, lateritic		4	124		
FERRICRETE, dark reddish-brown					
CLAY		8	120		
SAND, fine-grained, light to medium yellow					
CLAY, sandy, light to medium whitish-cream		12	116		Grout from surface to 53.4 mbgl
CLAY, lateritic		16	112		
		20	108		50 mm Class 18 PVC Environmental Casing
FERRICRETE, dark reddish-brown					
CLAY, ferruginous traces		24	104		
CLAY, sandy, light to medium whitish-cream		28	100		
		32	96		
CLAY, light to medium pinkish cream, lateritic		36	92		Water level - 38.45 mbgl - 16/7/2019
		40	88		
SAND, fine to medium-grained, orangey-cream		44	84		
GRAVEL, sandy					
SILTSTONE, medium to dark orangey-brown		48	80		
		52	76		
CARBONACEOUS SILTSTONE, black					Bentonite Seal - 53.4 to 54.4 mbgl
SILTSTONE, brownish-grey					
COAL, Pisces Upper Seam					Gravel Pack - 54.4 to 58.4 mbgl
SILTSTONE, brownish-grey		56	72		
COAL, Pisces Lower Upper 1 Seam					
SILTSTONE, light to dark grey					Screen - machine-slotted 50 mm PVC - 55.4 to 58.4 mbgl
COAL, Pisces Lower Upper 2 Seam		60			

JBT consulting

Easting: 732174.4

Northing: 7383256

Collar RL (mAHD): 128.64

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 58.69

Project: Gemini Project

Bore ID: DW7220W1

Drilled Date: 02-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL		0	128		Stickup to Lip of Steel Monument - 1.04 m
CLAY, medium to dark brown		2	126		
CLAY, sandy, medium to dark orangey-brown		4	124		
CLAY, light to medium yellowish-white		6	122		Grout from surface to 21.5 mbgl
		8	120		
		10	118		50 mm Class 18 PVC Environmental Casing
		12	116		
		14	114		
SAND		16	112		Water level - 15.38 mbgl - 19/7/2019
CLAY, light white		18	110		
CLAY, sandy, light to medium yellowish-cream		20	108		
CLAY, light to medium reddish-cream		22	106		Bentonite Seal - 21.5 to 22.5 mbgl
		24	104		Gravel Pack - 22.5 to 26.5 mbgl
GRAVEL, sandy, base of Tertiary at 26.5 mbgl		26	102		Screen - machine-slotted 50 mm PVC - 23.5 to 26.5 mbgl
		28			

JBT consulting

Easting: 729775

Northing: 7379648

Collar RL (mAHD): 128.68

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 26.5

Project: Gemini Project

Bore ID: DW7220W2

Drilled Date: 02-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL		0	128		Stickup to Lip of Steel Monument - 0.98 m
CLAY, medium to dark brown		2	126		
CLAY, sandy, medium to dark orangey-brown		4	124		
CLAY, light to medium yellowish-white		6	122		Grout from surface to 30.4 mbgl
		8	120		
		10	118		
		12	116		
		14	114		
SAND		16	112		50 mm Class 18 PVC Environmental Casing
CLAY, light white		18	110		
CLAY, sandy, light to medium yellowish-cream		20	108		Water level - 19.25 mbgl - 19/7/2019
CLAY, light to medium reddish-cream		22	106		
		24	104		
GRAVEL, sandy, base of Tertiary at 27 mbgl		26	102		
SILTSTONE, light to medium orangey-grown, clayey bands throughout		28	100		
		30	98		Bentonite Seal - 30.4 to 31.4 mbgl
		32	96		Gravel Pack - 31.4 to 38.4 mbgl
SANDSTONE, medium-grained, medium to dark orangey-brown		34	94		
		36	92		Screen - machine-slotted 50 mm PVC - 32.4 to 38.4 mbgl
COAL, Castor Seam, weathered		38	90		
SILTSTONE, medium to dark grey		40			

JBT consulting

Easting: 729774.5

Northing: 7379651

Collar RL (mAHD): 128.64

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 38.4

Project: Gemini Project

Bore ID: DW7220W3

Drilled Date: 02-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL		0	128		Stickup to Lip of Steel Monument - 0.99 m
CLAY, medium to dark brown					
CLAY, sandy, medium to dark orangey-brown		4	124		
CLAY, light to medium yellowish-white		8	120		Grout from surface to 71.5 mbgl
		12	116		
SAND		16	112		
CLAY, light white					
CLAY, sandy, light to medium yellowish-cream		20	108		Water level - 19.04 mbgl - 23/8/2019
CLAY, light to medium reddish-cream		24	104		
GRAVEL, sandy, base of Tertiary at 27 mbgl		28	100		
SILTSTONE, light to medium orangey-grown, clayey bands throughout		32	96		50 mm Class 18 PVC Environmental Casing
SANDSTONE, medium-grained, medium to dark orangey-brown		36	92		
COAL, Castor Seam, weathered					
SILTSTONE, medium to dark grey		40	88		
COAL, Castor Seam		44	84		
SILTSTONE, medium to dark grey, sandy bands		48	80		
SANDSTONE, fine to medium grained, medium to dark grey		52	76		
SILTSTONE, light to dark grey, sandy bands		56	72		
SANDSTONE, fine to medium grained, medium to dark grey		60	68		
CARBONACEOUS SILTSTONE, black		64	64		
COAL, Pisces Upper Seam		68	60		
SILTSTONE, medium to dark grey		72	56		Bentonite Seal - 71.5 to 72.5 mbgl
SANDSTONE, fine to medium grained, medium to dark grey		76	52		Gravel Pack - 72.5 to 75 mbgl
SANDSTONE, medium to coarse-grained, light to dark grey		80			Screen - machine-slotted 50 mm PVC - 73.5 to 75 mbgl
COAL, Pisces Lower Upper 1 Seam					
CARBONACEOUS SILTSTONE, black					

JBT consulting

Easting: 729774.4

Northing: 7379655

Collar RL (mAHD): 128.68

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 75.08

Project: Gemini Project

Bore ID: DW7221W1

Drilled Date: 03-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium brown		0	128		Stickup to Lip of Steel Monument - 1.02 m
CLAY, sandy, medium to dark orangey-brown		4	124		
CLAY, medium orangey-cream to purplish-cream		8	120		Grout from surface to 45.4 mbgl
CLAY, sandy, medium to dark creamy-white		12	116		
SAND, clayey, light to medium yellowish-cream		16	112		50 mm Class 18 PVC Environmental Casing
CLAY, sandy, medium to dark purplish-cream		20	108		Water level - 20.5 mbgl - 23/8/2019
SILTSTONE, medium to dark orangey-brown		24	104		
SANDSTONE, medium-grained, medium to dark orangey-brown		28	100		
COAL, weathered		32	96		
SANDSTONE, medium to dark orangey-brown		36	92		
SILTSTONE, medium to dark orangey-brown		40	88		
SANDSTONE		44	84		Bentonite Seal - 45.4 to 46.4 mbgl
SILTSTONE, medium to dark brownish-grey		48	80		Gravel Pack - 46.4 to 50.4 mbgl
COAL		52			Screen - machine-slotted 50 mm PVC - 47.4 to 50.4 mbgl
CARBONACEOUS SILTSTONE, black					
COAL, Aries 3 Seam					
SILTSTONE					

JBT consulting

Easting: 729846.2

Northing: 7379745

Collar RL (mAHD): 129.32

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 50.43

Project: Gemini Project

Bore ID: DW7221W2

Drilled Date: 03-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium brown		0	132		Stickup to Lip of Steel Monument - 1.07 m
CLAY, sandy, medium to dark orangey-brown		4	128		
CLAY, medium orangey-cream to purplish-cream		8	124		Grout from surface to 68.9 mbgl
CLAY, sandy, medium to dark creamy-white		12	120		
SAND, clayey, light to medium yellowish-cream		16	116		
CLAY, sandy, medium to dark purplish-cream		20	112		Water level - 20.5 mbgl - 23/8/2019
SILTSTONE, medium to dark orangey-brown		24	108		
SANDSTONE, medium-grained, medium to dark orangey-brown		28	104		
COAL, weathered		32	100		50 mm Class 18 PVC Environmental Casing
SANDSTONE, medium to dark orangey-brown		36	96		
SILTSTONE, medium to dark orangey-brown		40	92		
SANDSTONE		44	88		
SILTSTONE, medium to dark brownish-grey		48	84		
COAL		52	80		
CARBONACEOUS SILTSTONE, black		56	76		
COAL, Aries 3 Seam		60	72		
SILTSTONE		64	68		
SANDSTONE, fine to medium grained, dark grey, silty and sandy bands		68	64		
SANDSTONE, medium to coarse-grained, light to medium grey		72	60		Bentonite Seal - 68.9 to 69.9 mbgl
SANDSTONE, fine to medium grained, dark grey, silty and sandy bands		76	56		Gravel Pack - 69.9 to 72.4 mbgl
SILTSTONE, light to dark grey					Screen - machine-slotted 50 mm PVC - 70.9 to 72.4 mbgl
COAL					
SANDSTONE, medium to dark grey					
CARBONACEOUS SILTSTONE, black					
COAL, Castor Seam					
CARBONACEOUS SILTSTONE, black					

JBT consulting

Easting: 729844.6

Northing: 7379742

Collar RL (mAHD): 129.25

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 72.36

Project: Gemini Project

Bore ID: DW7225W1

Drilled Date: 14-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown		0	140		Stickup to Lip of Steel Monument - 1.06 m
CLAY, mottled purplish-cream		0 to 20	140 to 120		Grout from surface to 29 mbgl
CLAY, medium purplish-cream, lateritic		20 to 24	120 to 116		50 mm Class 18 PVC Environmental Casing
SAND, fine to medium-grained, light yellowish-brown, becoming medium to coarse near base		24 to 30	116 to 110		Bentonite Seal - 29 to 30 mbgl
CLAY, medium purplish-cream, lateritic		30 to 32	110 to 108		Gravel Pack - 30 to 37 mbgl
SAND, medium to coarse, light creamy-brown		32 to 34	108 to 106		Water level - 32.37 mbgl - 3/9/2019
CLAY, medium purplish-cream. Base of Tertiary at 37 mbgl		34 to 36	106 to 104		Screen - machine-slotted 50 mm PVC - 31 to 37 mbgl

JBT consulting

Easting: 730467.5

Northing: 7378359

Collar RL (mAHD): 140.64

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 37

Project: Gemini Project

Bore ID: DW7225W2

Drilled Date: 14-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown		0	140		Stickup to Lip of Steel Monument - 1.07 m
CLAY, mottled purplish-cream		5	135		
		10	130		Grout from surface to 73.9 mbgl
		15	125		
		20	120		50 mm Class 18 PVC Environmental Casing
CLAY, medium purplish-cream, lateritic		25	115		
SAND, fine to medium-grained, light yellowish-brown, becoming medium to coarse near base		30	110		
CLAY, medium purplish-cream, lateritic					
SAND, medium to coarse, light creamy-brown					Water level - 32.1 mbgl - 3/9/2019
CLAY, medium purplish-cream. Base of Tertiary at 37 mbgl		35	105		
SILTSTONE, medium to dark orangey-brown, becoming sandy towards base		40	100		
SANDSTONE, fine-grained, medium grey		45	95		
SILTSTONE, medium greyish-brown					
COAL, weathered		50	90		
CARBONACEOUS MUDSTONE					
SANDSTONE, fine to medium-grained, medium to dark grey					
SILTSTONE, medium grey, common sandstone bands		55	85		
SANDSTONE, medium grained, light grey					
SILTSTONE, medium grey		60	80		
SANDSTONE, fine to medium-grained, light to medium grey, abundant siltstone bands		65	75		
		70	70		
SILTSTONE, medium grey					
SANDSTONE, fine grained, medium to dark grey					Bentonite Seal - 73.9 to 74.9 mbgl
SILTSTONE, medium to dark grey		75	65		Gravel Pack - 74.9 to 78.9 mbgl
COAL, Aries 3 Seam					Screen - machine-slotted 50 mm PVC - 75.9 to 78.9 mbgl
CARBONACEOUS SILTSTONE, blackish-grey		80	60		

JBT consulting

Easting: 730465.7

Northing: 7378355

Collar RL (mAHD): 140.69

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 78.9

Project: Gemini Project

Bore ID: DW7225W3

Drilled Date: 13-Jun-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown		0	140		Stickup to Lip of Steel Monument - 1.04 m
CLAY, mottled purplish-cream		10	130		Grout from surface to 107.8 mbgl
CLAY, medium purplish-cream, lateritic		20	120		50 mm Class 18 PVC Environmental Casing
SAND, fine to medium-grained, light yellowish-brown, becoming medium to coarse near base					
CLAY, medium purplish-cream, lateritic		30	110		Water level - 31.6 mbgl - 3/9/2019
SAND, medium to coarse, light creamy-brown					
CLAY, medium purplish-cream. Base of Tertiary at 37 mbgl					
SILTSTONE, medium to dark orangey-brown, becoming sandy towards base		40	100		
SANDSTONE, fine-grained, medium grey					
SILTSTONE, medium greyish-brown		50	90		
COAL, weathered					
CARBONACEOUS MUDSTONE					
SANDSTONE, fine to medium-grained, medium to dark grey					
SILTSTONE, medium grey, common sandstone bands					
SANDSTONE, medium grained, light grey		60	80		
SILTSTONE, medium grey					
SANDSTONE, fine to medium-grained, light to medium grey, abundant siltstone bands		70	70		
SILTSTONE, medium grey					
SANDSTONE, fine grained, medium to dark grey					
SILTSTONE, medium to dark grey					
COAL, Aries 3 Seam					
CARBONACEOUS SILTSTONE, blackish-grey		80	60		
SILTSTONE, dark grey					
SANDSTONE, fine grained, light to medium grey					
SILTSTONE, medium grey, common sandstone bands					
SANDSTONE, fine grained, common siltstone bands		90	50		
SANDSTONE, fine grained, light to medium grey		100	40		
COAL, Castor Seam		110	30		Bentonite Seal - 107.8 to 108.8 mbgl Gravel Pack - 108.8 to 112.8 mbgl Screen - machine-slotted 50 mm PVC - 109.8 to 112.8 mbgl
CARBONACEOUS SILTSTONE, blackish-grey					
		120			

JBT consulting

Easting: 730464.7

Northing: 7378351

Collar RL (mAHD): 140.7

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 112.8

Project: Gemini Project

Bore ID: DW7264W1

Drilled Date: 14-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
		1	113		Stickup to Lip of Steel Monument - 0.98 m
SOIL, medium to dark brown		0	112		
CLAY		1	111		
SILCRETE, medium to dark orangey-brown		2	110		
CLAY, sandy, medium to dark brown		3	109		Grout from surface to 10.5 mbgl
		4	108		
		5	107		
		6	106		50 mm Class 18 PVC Environmental Casing
		7	105		
		8	104		Water level - DRY - 25/7/2018
CLAY, medium to dark orangey-brown, base of Tertiary at 14 mbgl		9	103		
		10	102		
		11	101		Bentonite Seal - 10.5 to 11.5 mbgl
		12	100		Gravel Pack - 11.5 to 14 mbgl
		13	99		Screen - machine-slotted 50 mm PVC - 12.5 to 14 mbgl
		14			

JBT consulting

Easting: 733392.2

Northing: 7382915

Collar RL (mAHD): 112.18

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 14

Project: Gemini Project

Bore ID: DW7264W2

Drilled Date: 14-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown CLAY SILCRETE, medium to dark orangey-brown CLAY, sandy, medium to dark brown CLAY, medium to dark orangey-brown, base of Tertiary at 14 mbgl		0 10	110 100		Stickup to Lip of Steel Monument - 0.98 m Grout from surface to 100.7 mbgl
SILTSTONE, medium to dark brownish-grey		20	90		Water level - 21.59 mbgl - 15/7/2019
SANDSTONE, fine grained, medium to dark brownish grey, minor siltstone bands, base of weathering at 42 mbgl		30 40	80 70		50 mm Class 18 PVC Environmental Casing
SANDSTONE, fine to medium-grained, medium to dark grey, fresh		50	60		
SILTSTONE, light to dark grey, minor sandstone bands					
SANDSTONE, fine to medium-grained, medium to dark grey		60	50		
SILTSTONE, light to dark grey		70	40		
SANDSTONE, fine grained, medium to dark grey, minor siltstone bands		80	30		
SILTSTONE, light to dark grey, minor sandstone bands		90	20		
COAL, Aries 1 Upper Seam SILTSTONE, light to dark grey COAL, Aries 1 Lower Seam SILTSTONE, light to dark grey		100 110	10		Bentonite Seal - 100.7 to 101.7 mbgl Gravel Pack - 101.7 to 104.2 mbgl Screen - machine-slotted 50 mm PVC - 102.7 to 104.2 mbgl

JBT consulting

Easting: 733391.5

Northing: 7382921

Collar RL (mAHD): 112.24

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 104.21

Project: Gemini Project

Bore ID: DW7264W3

Drilled Date: 13-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, medium to dark brown		0	110		Stickup to Lip of Steel Monument - 1.00 m
CLAY					
SILCRETE, medium to dark orangey-brown					
CLAY, sandy, medium to dark brown		10	100		Grout from surface to 133.2 mbgl
CLAY, medium to dark orangey-brown, base of Tertiary at 14 mbgl					
SILTSTONE, medium to dark brownish-grey		20	90		Water level - 21.58 mbgl - 15/7/2019
		30	80		50 mm Class 18 PVC Environmental Casing
SANDSTONE, fine grained, medium to dark brownish grey, minor siltstone bands, base of weathering at 42 mbgl		40	70		
SANDSTONE, fine to medium-grained, medium to dark grey, fresh		50	60		
SILTSTONE, light to dark grey, minor sandstone bands		60	50		
SANDSTONE, fine to medium-grained, medium to dark grey					
SILTSTONE, light to dark grey		70	40		
SANDSTONE, fine grained, medium to dark grey, minor siltstone bands		80	30		
SILTSTONE, light to dark grey, minor sandstone bands		90	20		
COAL, Aries 1 Upper Seam		100	10		
SILTSTONE, light to dark grey					
COAL, Aries 1 Lower Seam					
SILTSTONE, light to dark grey					
SANDSTONE, medium to dark grey, fine to medium-grained, becoming medium to coarse-grained at base		110	0		
SILTSTONE, light to dark grey					
COAL, Aries 2 Seam					
SILTSTONE, light to dark grey		120	10		
SANDSTONE, medium to dark grey, fined to medium grained, medium to coarse-grained in middle of unit					
SILTSTONE, light to dark grey		130	20		
COAL, Aries 3 Seam					Bentonite Seal - 133.2 to 134.2 mbgl
CARBONACEOUS SILTSTONE, black		140	30		Gravel Pack - 134.2 to 136.7 mbgl Screen - machine-slotted 50 mm PVC - 135.2 to 136.7 mbgl
		150			

JBT consulting

Easting: 733390.9

Northing: 7382925

Collar RL (mAHD): 112.24

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 136.7

Project: Gemini Project

Bore ID: DW7282W1

Drilled Date: 26-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, light brown SAND, light creamy-white CLAY, light whitish-grey, lithic traces		0	116		Stickup to Lip of Steel Monument - 1.00 m
FERRICRETE, dark reddish-brown CLAY		4	112		
SILCRETE, light brownish-grey CLAY, light to medium brownish grey with lithic traces and ferruginous lenses, base of Tertiary at 13 mbgl		8	108		Grout from surface to 35 mbgl
		12	104		
SILTSTONE, medium to dark brownish-grey		16	100		
		20	96		50 mm Class 18 PVC Environmental Casing
LIMONITE, light to medium brownish-yellow		24	92		
SILTSTONE, medium to dark brownish-grey, base of weathering at 29 mbgl		28	88		Water level - 26.25 mbgl - 18/7/2019
SANDSTONE, fine to medium-grained, medium to dark grey		32	84		
SILTSTONE, medium to dark grey		36	80		Bentonite Seal - 35 to 36 mbgl
		40	76		Gravel Pack - 36 to 43 mbgl Screen - machine-slotted 50 mm PVC - 37 to 43 mbgl
		44	72		

JBT consulting

Easting: 732118.6

Northing: 7381433

Collar RL (mAHD): 115.84

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 43.03

Project: Gemini Project

Bore ID: DW7282W2

Drilled Date: 25-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
SOIL, light brown		0	115		Stickup to Lip of Steel Monument - 0.99 m
SAND, light creamy-white					
CLAY, light whitish-grey, lithic traces		5	110		
FERRICRETE, dark reddish-brown					
CLAY					
SILCRETE, light brownish-grey					
CLAY, light to medium brownish grey with lithic traces and ferruginous lenses, base of Tertiary at 13 mbgl		10	105		Grout from surface to 86.4 mbgl
SILTSTONE, medium to dark brownish-grey		15	100		
		20	95		50 mm Class 18 PVC Environmental Casing
LIMONITE, light to medium brownish-yellow		25	90		Water level - 26.32 mbgl - 18/7/2019
SILTSTONE, medium to dark brownish-grey, base of weathering at 29 mbgl					
SANDSTONE, fine to medium-grained, medium to dark grey		30	85		
SILTSTONE, medium to dark grey		35	80		
		40	75		
SANDSTONE, fine to medium-grained, light to dark grey					
SILTSTONE, dark grey		45	70		
SANDSTONE, fine to medium-gained, light to medium grey					
SILTSTONE, medium to dark grey, with sandstone and siderite bands		50	65		
COAL, Aries 1 Seam					
CARBONACEOUS SILTSTONE, black					
SILTSTONE, medium to dark grey		55	60		
SANDSTONE, fine to medium grained, becoming medium to coarse grained towards base, light to dark grey with carbonaceous claystone and siderite bands		60	55		
		65	50		
		70	45		
SILTSTONE, medium to dark grey					
COAL, Aries 2 Seam		75	40		
SILTSTONE, medium to dark grey					
SANDSTONE, medium to coarse-grained, light to dark grey					
SILTSTONE, medium to dark grey					
SANDSTONE, fine-grained, medium to dark grey		80	35		
SILTSTONE, medium to dark grey					
SANDSTONE, fine to medium-grained, medium to dark grey					
SILTSTONE, dark grey		85	30		Bentonite Seal - 86.4 to 87.4 mbgl
COAL, Aries 3 Seam					Gravel Pack - 87.4 to 89.9 mbgl
SILTSTONE, dark blackish-grey		90	25		Screen - machine-slotted 50 mm PVC - 88.4 to 89.9 mbgl
		95			

JBT consulting

Easting: 732122.9

Northing: 7381433

Collar RL (mAHD): 115.83

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 89.91

Project: Gemini Project

Bore ID: DW7292W1

Drilled Date: 26-May-2019

Lithological Description	Graphic Log	Depth (m)	Elevation (mAHD)	Bore Design	Bore Construction/ General Drilling Notes
		1	114		Stickup to Lip of Steel Monument - 0.83 m
SOIL, medium to dark brown		0			
		1	113		
CLAY, medium to dark orangey-brown		2	112		
		3	111		Grout from surface to 10 mbgl
		4	110		
Silty CLAY, light to dark grey		5	109		
		6	108		
		7	107		50 mm Class 18 PVC Environmental Casing
Sandy CLAY, medium to dark brownish-orange		8	106		
		9	105		
FERRICRETE, dark reddish-brown		10	104		
		11	103		Bentonite Seal - 10 to 11 mbgl
Silty CLAY, light white, lithic traces		12	102		Water level - 11.19 mbgl - 23/8/2019
		13	101		Gravel Pack - 11 to 15 mbgl
FERRICRETE, dark reddish-brown		14	100		Screen - machine-slotted 50 mm PVC - 12 to 15 mbgl
Silty CLAY, light white, lithic traces		15	99		

JBT consulting

Easting: 732904.7

Northing: 7381108

Collar RL (mAHD): 113.58

Co-ord System: GDA94

Drilling Company: Hodge Drilling

Drill Rig:

Hole Diameter (mm): 120

Total Depth (m): 15

APPENDIX B

GROUNDWATER CHEMISTRY DATA

Appendix B1: pH, EC, TDS, Major Ion Data

Site	Groundwater Unit	Date	pH (Lab)	pH (Field)	EC (Lab)	EC (Field)	TDS	Na	Ca	Mg	K	Cl	SO4	Alkalinity			
														Carbonate	Bicarbonate	Hydroxide	Total
			Unit	Unit	µS/cm	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DW7065W	AR3	12-Dec-2018	8.21	6.33	28400	27187	19800	4720	439	724	24	9380	679	<1	608	<1	608
DW7065W	AR3	07-Jan-2019	6.85	6.37	27300	28450	19700	5190	456	849	24	9470	711	<1	589	<1	589
DW7065W	AR3	18-Feb-2019	6.81	6.42	28200	28360	19100	5100	458	774	23	9720	789	<1	568	<1	568
DW7065W	AR3	11-Mar-2019	7.01	6.46	28100	27619	19700	5390	508	846	24	9970	781	<1	583	<1	583
DW7065W	AR3	17-Apr-2019	7.03	6.45	26800	27639	19200	5000	551	815	24	9750	733	<1	599	<1	599
DW7065W	AR3	13-May-2019	7.11	6.48	25800	27367	19300	5010	442	792	24	9620	776	<1	610	<1	610
DW7065W	AR3	19-Jun-2019		6.59		27033		4820	516	760	22	9730	763	<1	592	<1	592
DW7065W	AR3	11-Jul-2019	7.78		27400		18100	4860	482	757	26	9120	741	<1	654	<1	654
DW7065W	AR3	26-Aug-2019	7.05	6.47	27400	27509	18900	4740	488	752	24	10200	826	<1	614	<1	614
DW7067W	AR3	12-Dec-2018	8.21	6.29	28500	27457	19900	4660	421	729	26	9590	716	<1	589	<1	589
DW7067W	AR3	07-Jan-2019	6.86	6.29	28000	29175	19900	5040	471	863	28	9720	767	<1	599	<1	599
DW7067W	AR3	18-Feb-2019	6.79	6.38	28500	28613	19300	5160	456	793	27	9820	841	<1	580	<1	580
DW7067W	AR3	11-Mar-2019	6.99	6.45	28500	28023	20500	5480	494	865	26	10100	780	<1	603	<1	603
DW7067W	AR3	17-Apr-2019	6.98	6.41	27200	28021	18600	5060	540	820	27	9750	746	<1	597	<1	597
DW7067W	AR3	13-May-2019	7.01	6.43	26300	28004	20100	5130	435	816	27	9840	764	<1	608	<1	608
DW7067W	AR3	19-Jun-2019		6.84		27800		4900	508	808	26	10100	798	<1	583	<1	583
DW7067W	AR3	11-Jul-2019	7.73		28400		19000	4930	462	784	26	9400	777	<1	634	<1	634
DW7067W	AR3	26-Aug-2019	7.04	6.43	27700	27930	19200	4740	482	769	27	10400	837	<1	614	<1	614
DW7069W	Castor Lower/Pollux Upper	12-Dec-2018	8.28	6.3	25500	24484	17600	4590	349	627	23	8490	623	<1	587	<1	587
DW7069W	Castor Lower/Pollux Upper	07-Jan-2019	6.87	6.25	25000	25868	17700	4500	321	636	21	8670	610	<1	580	<1	580
DW7069W	Castor Lower/Pollux Upper	18-Feb-2019	6.77	6.33	22100	22731	14500	4210	312	553	20	7720	645	<1	530	<1	530
DW7069W	Castor Lower/Pollux Upper	11-Mar-2019	6.92	6.38	23500	23087	16300	4590	352	634	22	8590	387	<1	566	<1	566
DW7069W	Castor Lower/Pollux Upper	17-Apr-2019	7.02	6.33	23000	23682	14900	4300	396	612	21	8210	618	<1	578	<1	578
DW7069W	Castor Lower/Pollux Upper	13-May-2019	6.91	6.39	22600	23989	16000	4110	299	574	20	8470	653	<1	595	<1	595
DW7069W	Castor Lower/Pollux Upper	19-Jun-2019		6.51		24483		4280	388	622	21	8800	671	<1	573	<1	573
DW7069W	Castor Lower/Pollux Upper	11-Jul-2019	7.67		24800		16400	4340	343	606	21	8270	642	<1	606	<1	606
DW7069W	Castor Lower/Pollux Upper	26-Aug-2019	6.98	6.36	24500	24741	16800	4350	379	615	23	9090	762	<1	599	<1	599
DW7073W	Castor Lower/Pollux Upper	13-Dec-2018	8.23	6.26	24500	23392	17100	4340	423	485	21	8240	341	<1	411	<1	411
DW7073W	Castor Lower/Pollux Upper	07-Jan-2019	6.84	6.21	24100	25049	16800	4380	401	512	20	8150	346	<1	423	<1	423
DW7073W	Castor Lower/Pollux Upper	18-Feb-2019	6.77	6.32	24100	24459	16000	4530	432	502	21	8180	404	<1	414	<1	414
DW7073W	Castor Lower/Pollux Upper	11-Mar-2019	6.97	6.39	24300	23980	17200	4930	483	557	22	9080	550	<1	436	<1	436
DW7073W	Castor Lower/Pollux Upper	17-Apr-2019	6.98	6.33	23100	23847	16400	4380	514	517	21	8470	387	<1	423	<1	423
DW7073W	Castor Lower/Pollux Upper	13-May-2019	6.94	6.38	22600	23963	15900	4180	367	477	20	8510	388	<1	449	<1	449
DW7073W	Castor Lower/Pollux Upper	19-Jun-2019		6.52		23989		4230	476	501	20	8780	383	<1	422	<1	422
DW7073W	Castor Lower/Pollux Upper	11-Jul-2019	7.64		24400		15800	4300	430	498	20	8160	373	<1	452	<1	452
DW7073W	Castor Lower/Pollux Upper	26-Aug-2019	6.98	6.35	24000	24057	15800	4280	452	491	21	8730	417	<1	460	<1	460
DW7074W	Castor Upper	13-Dec-2018	8.34	6.71	26100	25085	18000	4720	327	606	25	8670	488	20	585	<1	605
DW7074W	Castor Upper	07-Jan-2019	7.18	6.57	25500	26576	18200	4650	302	616	23	8890	511	<1	624	<1	624
DW7074W	Castor Upper	18-Feb-2019	6.99	6.55	25700	26043	16900	4880	329	605	24	8920	600	<1	605	<1	605
DW7074W	Castor Upper	11-Mar-2019	7.23	6.65	26000	25523	18000	5060	350	654	23	9220	574	<1	642	<1	642
DW7074W	Castor Upper	17-Apr-2019	7.19	6.56	24500	25280	17000	4700	380	619	23	8850	546	<1	620	<1	620
DW7074W	Castor Upper	13-May-2019	7.17	6.59	24200	25440	16900	4450	285	571	22	8980	570	<1	637	<1	637
DW7074W	Castor Upper	19-Jun-2019		6.69		25929		4640	372	612	22	9080	560	<1	635	<1	635
DW7074W	Castor Upper	11-Jul-2019	7.8		25800		16900	4790	332	612	23	8570	528	<1	661	<1	661
DW7074W	Castor Upper	26-Aug-2019	7.2	6.55	25300	25483	17000	4570	358	587	24	9180	578	<1	634	<1	634
DW7076W	Alluvium	12-Dec-2018	8.04	7.24	16200	14782	10600	2410	42	279	10	4170	214	<1	3600	<1	3600
DW7076W	Alluvium	07-Jan-2019	8.04	7.05	16600	17106	10500	3720	62	407	15	4290	205	<1	3620	<1	3620
DW7076W	Alluvium	18-Feb-2019	7.57	7.2	16000	16262	10000	3490	67	368	13	4140	231	<1	3480	<1	3480
DW7076W	Alluvium	11-Mar-2019	7.66	7.37	16200	16145	10400	3760	65	383	14	4190	249	<1	3540	<1	3540
DW7076W	Alluvium	17-Apr-2019	7.37	7.38	15400	15760	10300	3420	73	357	14	4060	212	<1	3510	<1	3510

Appendix B1: pH, EC, TDS, Major Ion Data

Site	Groundwater Unit	Date	pH (Lab)	pH (Field)	EC (Lab)	EC (Field)	TDS	Na	Ca	Mg	K	Cl	SO4	Alkalinity			
														Carbonate	Bicarbonate	Hydroxide	Total
			Unit	Unit	µS/cm	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DW7076W	Alluvium	13-May-2019	7.84	7.36	15200	15632	10100	3370	47	329	15	4120	204	<1	3680	<1	3680
DW7076W	Alluvium	19-Jun-2019		7.49		15602		3340	49	335	13	4030	220	<1	3480	<1	3480
DW7076W	Alluvium	11-Jul-2019	7.76		15400		9980	3410	48	317	15	3750	210	<1	1840	<1	1840
DW7076W	Alluvium	26-Aug-2019	7.79	7.29	15300	14975	9200	3170	45	292	16	4040	209	562	2960	<1	3520
DW7068W	Tertiary	12-Dec-2018	8.29	6.86	20200	19273	14000	3530	216	523	101	6940	291	<1	607	<1	607
DW7068W	Tertiary	07-Jan-2019	7.26	6.78	20600	21433	14300	3710	211	575	82	7240	295	<1	601	<1	601
DW7068W	Tertiary	18-Feb-2019	7.23	6.98	21000	21493	13400	3880	226	563	77	7390	344	<1	578	<1	578
DW7068W	Tertiary	11-Mar-2019	7.38	6.95	21200	20960	14900	4040	234	596	73	8160	635	<1	593	<1	593
DW7068W	Tertiary	17-Apr-2019	7.57	7.06	20800	21270	13700	3780	259	577	72	7480	338	<1	600	<1	600
DW7068W	Tertiary	13-May-2019	7.42	6.93	20200	21301	14700	3790	202	568	72	7650	334	<1	602	<1	602
DW7068W	Tertiary	11-Jul-2019	7.89		21900		14300	4120	246	647	68	7220	334	<1	619	<1	619
Alluvium	Count			8	8	8	8	9	9	9	9	9	9	1	9	0	9
	Min			7.05	15200	14782	9200	2410	42	279	10	3750	204	562	1840		1840
	Max			7.49	16600	17106	10600	3760	73	407	16	4290	249	562	3680		3680
	Mean			7.2975	15788	15783	10135	3343	55	341	14	4088	217		3301		3363
	Median			7.325	15700	15696	10200	3410	49	335	14	4120	212		3510		3520
	StDev			0.13	491	691	413	373	11	40	2	142	14		553		542
Tertiary	Count			6	7	6	7	7	7	7	7	7	7	0	7	0	7
	Min			6.78	20200	19273	13400	3530	202	523	68	6940	291		578		578
	Max			7.06	21900	21493	14900	4120	259	647	101	8160	635		619		619
	Mean			6.93	20843	20955	14186	3836	228	578	78	7440	367		600		600
	Median			6.94	20800	21286	14300	3790	226	575	73	7390	334		601		601
	StDev			0.09	555	771	491	185	19	35	10	360	111		12		12
Coal Seams	Count			40	40	40	40	45	45	45	45	45	45	1	45	0	45
	Min			6.21	22100	22731	14500	4110	285	477	20	7720	341	20	411		411
	Max			6.84	28500	29175	20500	5480	551	865	28	10400	841		661		661
	Mean			6.44	25693	25934	17760	4694	417	663	23	9081	622		568		569
	Median			6.42	25600	25696	17650	4700	430	622	23	9080	642		592		595
	StDev			0.14	1913	1823	1573	343	72	121	2	661	153		73		73

Appendix B2: Dissolved Metals/ Metalloid Data

Site	Groundwater Unit	Date	Al (diss)	As (diss)	Ba (diss)	Be (diss)	B (diss)	Cd (diss)	Cr (diss)	Co (diss)	Cu (diss)	Fe (diss)	Pb (diss)	Mn (diss)	Hg (diss)	Mo (diss)	Ni (diss)	Se (diss)	Ag (diss)	U (diss)	V (diss)	Zn (diss)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC 2000 - 95% Freshwater Species Protection			**0.055**	**0.013**			**0.37**	**0.0002**	**0.001**		**0.0014**		**0.0034**	**1.9**	**0.0006**		**0.011**	**0.011**	**0.00005**			**0.008**
DW7065W	AR3	12-Dec-2018	0.01	0.023	0.076	<0.001	1.22	0.0002	<0.001	0.019	0.081	2.48	0.007	0.312	<0.0001	0.002	0.022	<0.01	<0.001	0.016	<0.01	0.21
DW7065W	AR3	07-Jan-2019	<0.01	0.029	0.168	<0.001	1.2	0.0001	<0.001	0.011	0.005	2.82	<0.001	0.247	<0.0001	0.002	0.015	<0.01	<0.001	0.01	<0.01	0.176
DW7065W	AR3	18-Feb-2019	<0.01	0.02	0.117	<0.001	1.37	<0.0001	<0.001	0.009	0.002	4.41	<0.001	0.227	<0.0001	0.001	0.017	<0.01	<0.001	0.008	<0.01	0.03
DW7065W	AR3	11-Mar-2019	<0.05	0.012	0.075	<0.005	1.21	<0.0005	<0.005	0.009	<0.005	3.99	<0.005	0.295	<0.0001	<0.005	0.011	<0.05	<0.005	<0.005	<0.05	0.075
DW7065W	AR3	17-Apr-2019	<0.01	0.019	0.105	<0.001	1.27	<0.0001	<0.001	0.007	0.001	3.43	<0.001	0.249	<0.0005	0.001	0.009	<0.01	<0.001	0.007	<0.01	0.094
DW7065W	AR3	13-May-2019	<0.01	0.019	0.279	<0.001	1.25	<0.0001	<0.001	0.007	0.003	3.74	<0.001	0.327	<0.0001	<0.001	0.013	<0.01	<0.001	0.008	<0.01	0.136
DW7065W	AR3	19-Jun-2019	<0.01	0.018	0.184	<0.001	1.1	<0.0001	<0.001	0.008	<0.001	3.99	<0.001	0.318	<0.0001	<0.001	0.013	<0.01	<0.001	0.008	<0.01	0.103
DW7065W	AR3	11-Jul-2019	<0.05	0.006	0.276	<0.005	1.29	<0.0005	<0.005	0.005	<0.005	1.55	<0.005	0.397	<0.0001	<0.005	0.013	<0.05	<0.005	0.005	<0.05	0.105
DW7065W	AR3	26-Aug-2019	<0.01	0.018	0.477	<0.001	1.25	<0.0001	<0.001	0.006	<0.001	4.37	<0.001	0.293	<0.0001	0.006	0.01	<0.01	<0.001	0.008	<0.01	0.07
DW7067W	AR3	12-Dec-2018	<0.01	0.006	0.06	<0.001	1.26	<0.0001	<0.001	0.005	0.047	1.99	0.004	0.107	<0.0001	0.001	0.007	<0.01	<0.001	0.004	<0.01	0.105
DW7067W	AR3	07-Jan-2019	<0.05	0.012	0.087	<0.005	1.48	<0.0005	<0.005	<0.005	0.009	2.85	<0.005	0.119	<0.0001	<0.005	<0.005	<0.05	<0.005	<0.005	<0.05	0.147
DW7067W	AR3	18-Feb-2019	<0.01	0.012	0.077	<0.001	1.44	<0.0001	<0.001	0.002	0.002	4.23	<0.001	0.104	<0.0001	0.001	0.007	<0.01	<0.001	0.003	<0.01	0.047
DW7067W	AR3	11-Mar-2019	<0.05	0.008	0.066	<0.005	1.22	<0.0005	<0.005	<0.005	<0.005	3.61	<0.005	0.103	<0.0001	<0.005	<0.005	<0.05	<0.005	<0.005	<0.05	0.062
DW7067W	AR3	17-Apr-2019	<0.01	0.008	0.068	<0.001	1.34	<0.0001	<0.001	0.001	<0.001	3.35	<0.001	0.105	<0.0001	<0.001	0.003	<0.01	<0.001	0.002	<0.01	0.066
DW7067W	AR3	13-May-2019	<0.01	0.007	0.133	<0.001	1.23	<0.0001	<0.001	0.001	0.014	3.02	<0.001	0.114	<0.0001	<0.001	0.005	<0.01	<0.001	0.002	<0.01	0.094
DW7067W	AR3	19-Jun-2019	<0.01	0.004	0.096	<0.001	1.2	<0.0001	<0.001	0.002	0.005	0.43	<0.001	0.087	<0.0001	0.001	0.006	<0.01	<0.001	0.002	<0.01	0.088
DW7067W	AR3	11-Jul-2019	<0.05	<0.005	0.129	<0.005	1.38	<0.0005	<0.005	<0.005	<0.005	2.16	<0.005	0.151	<0.0001	<0.005	0.009	<0.05	<0.005	<0.005	<0.05	0.143
DW7067W	AR3	26-Aug-2019	<0.01	0.006	0.183	<0.001	1.32	<0.0001	<0.001	0.001	<0.001	3	<0.001	0.114	<0.0001	0.002	0.006	<0.01	<0.001	0.002	<0.01	0.059
DW7069W	Castor Lower/Pollux Upper	12-Dec-2018	<0.01	0.003	0.059	<0.001	1.25	0.0001	<0.001	0.002	0.067	2.16	0.003	0.19	<0.0001	0.002	0.005	<0.01	<0.001	0.002	<0.01	0.146
DW7069W	Castor Lower/Pollux Upper	07-Jan-2019	<0.01	0.004	0.066	<0.001	1.15	<0.0001	<0.001	<0.001	0.024	2.45	<0.001	0.168	<0.0001	0.002	0.003	<0.01	<0.001	0.001	<0.01	0.124
DW7069W	Castor Lower/Pollux Upper	18-Feb-2019	<0.01	0.003	0.072	<0.001	1.4	<0.0001	<0.001	<0.001	0.008	2.37	<0.001	0.157	<0.0001	0.001	0.005	<0.01	<0.001	<0.001	<0.01	0.085
DW7069W	Castor Lower/Pollux Upper	11-Mar-2019	<0.05	<0.005	0.062	<0.005	1.11	<0.0005	<0.005	<0.005	<0.005	2.31	<0.005	0.173	<0.0001	<0.005	<0.005	<0.05	0.007	<0.005	<0.05	0.068
DW7069W	Castor Lower/Pollux Upper	17-Apr-2019	<0.01	0.002	0.06	<0.001	1.3	<0.0001	<0.001	<0.001	0.002	2.38	<0.001	0.162	<0.0001	0.001	0.002	<0.01	<0.001	<0.001	<0.01	0.064
DW7069W	Castor Lower/Pollux Upper	13-May-2019	<0.01	0.003	0.104	<0.001	1.23	<0.0001	<0.001	<0.001	0.011	2.22	<0.001	0.161	<0.0001	0.002	0.003	<0.01	<0.001	<0.001	<0.01	0.07
DW7069W	Castor Lower/Pollux Upper	19-Jun-2019	<0.01	0.003	0.081	<0.001	1.18	<0.0001	<0.001	<0.001	0.005	2.34	<0.001	0.157	<0.0001	0.001	0.004	<0.01	<0.001	<0.001	<0.01	0.101
DW7069W	Castor Lower/Pollux Upper	11-Jul-2019	<0.05	<0.005	0.085	<0.005	1.34	<0.0005	<0.005	<0.005	<0.005	1.83	<0.005	0.159	<0.0001	<0.005	0.007	<0.05	<0.005	<0.005	<0.05	0.129
DW7069W	Castor Lower/Pollux Upper	26-Aug-2019	<0.01	0.003	0.103	<0.001	1.3	<0.0001	<0.001	<0.001	0.002	2.63	<0.001	0.158	<0.0001	0.001	0.004	<0.01	<0.001	<0.001	<0.01	0.045
DW7073W	Castor Lower/Pollux Upper	13-Dec-2018	<0.01	<0.001	0.116	<0.001	1.04	<0.0001	<0.001	<0.001	0.047	1.13	<0.001	0.306	<0.0001	0.002	0.004	<0.01	<0.001	<0.001	<0.01	0.103
DW7073W	Castor Lower/Pollux Upper	07-Jan-2019	<0.01	<0.001	0.118	<0.001	0.94	<0.0001	<0.001	<0.001	0.018	1.85	<0.001	0.325	<0.0001	0.002	0.002	<0.01	<0.001	<0.001	<0.01	0.096
DW7073W	Castor Lower/Pollux Upper	18-Feb-2019	<0.01	0.001	0.132	<0.001	1.18	<0.0001	<0.001	<0.001	0.013	3.52	<0.001	0.339	<0.0001	0.002	0.005	<0.01	<0.001	<0.001	<0.01	0.097
DW7073W	Castor Lower/Pollux Upper	11-Mar-2019	<0.05	<0.005	0.122	<0.005	0.88	<0.0005	<0.005	<0.005	0.008	3.99	<0.005	0.352	<0.0001	<0.005	<0.005	<0.05	<0.005	<0.005	<0.05	0.068
DW7073W	Castor Lower/Pollux Upper	17-Apr-2019	<0.01	0.002	0.11	<0.001	1.05	<0.0001	<0.001	<0.001	0.002	4.22	<0.001	0.337	<0.0001	0.002	0.002	<0.01	<0.001	<0.001	<0.01	0.058
DW7073W	Castor Lower/Pollux Upper	13-May-2019	<0.01	0.002	0.153	<0.001	0.99	<0.0001	<0.001	<0.001	0.007	3.95	<0.001	0.323	<0.0001	0.002	0.002	<0.01	<0.001	<0.001	<0.01	0.048
DW7073W	Castor Lower/Pollux Upper	19-Jun-2019	<0.01	0.002	0.119	<0.001	1.07	<0.0001	<0.001	<0.001	0.003	3.94	<0.001	0.334	<0.0001	0.002	0.002	<0.01	<0.001	<0.001	<0.01	0.084
DW7073W	Castor Lower/Pollux Upper	11-Jul-2019	<0.05	<0.005	0.123	<0.005	1.15	<0.0005	<0.005	<0.005	<0.005	3.37	<0.005	0.335	<0.0001	<0.005	0.005	<0.05	<0.005	<0.005	<0.05	0.118
DW7073W	Castor Lower/Pollux Upper	26-Aug-2019	<0.01	0.001	0.137	<0.001	1.02	<0.0001	<0.001	<0.001	<0.001	3.84	<0.001	0.315	<0.0001	0.002	0.003	<0.01	<0.001	<0.001	<0.01	0.038
DW7074W	Castor Upper	13-Dec-2018	0.02	0.001	0.079	<0.001	1.33	<0.0001	<0.001	0.001	0.032	<0.05	0.002	0.216	<0.0001	0.01	0.004	<0.01	<0.001	0.002	<0.01	0.087
DW7074W	Castor Upper	07-Jan-2019	<0.01	0.001	0.086	<0.001	1.19	<0.0001	<0.001	0.001	0.015	0.08	<0.001	0.24	<0.0001	0.008	0.003	<0.01	<0.001	0.003	<0.01	0.065
DW7074W	Castor Upper	18-Feb-2019	<0.01	0.002	0.086	<0.001	1.45	<0.0001	<0.001	0.002	0.013	0.29	<0.001	0.243	<0.0001	0.007	0.006	<0.01	<0.001	0.003	<0.01	0.065
DW7074W	Castor Upper	11-Mar-2019	<0.05	<0.005	0.072	<0.005	1.13	<0.0005	<0.005	<0.005	<0.005	1.47	<0.005	0.249	<0.0001	<0.005	<0.005	<0.05	<0.005	<0.005	<0.05	0.043
DW7074W	Castor Upper	17-Apr-2019	<0.01	0.005	0.068	<0.001	1.3	<0.0001	<0.001	0.001	<0.001	1.74	<0.001	0.228	<0.0001	0.005	0.003	<0.01	<0.001	0.002	<0.01	0.042
DW7074W	Castor Upper	13-May-2019	<0.01	0.005	0.104	<0.001	1.28	<0.0001	<0.001	<0.001	0.008	2.41	<0.001	0.251	<0.0001	0.004	0.004	<0.01	<0.001	0.003	<0.01	0.046
DW7074W	Castor Upper	19-Jun-2019	<0.01	0.006	0.083	<0.001	1.34	<0.0001	<0.001	<0.001	0.006	1.8	<0.001	0.237	<0.0001	0.006	0.005	<0.01	<0.001	0.002	<0.01	0.073
DW7074W	Castor Upper	11-Jul-2019	<0.05	<0.005	0.094	<0.005	1.49	<0.0005	<0.005	<0.005	<0.005	0.96	<0.005	0.258	<0.0001	<0.005	0.008	<0.05	<0.005	<0.005	<0.05	0.067
DW7074W	Castor Upper	26-Aug-2019	0.01	0.002	0.106	<0.001	1.31	<0.0001	<0.001	<0.001	<0.001	1.68	<0.001	0.258	<0.0001	0.004	0.005	<0.01	<0.001	0.002	<0.01	0.025
DW7068W	Tertiary	12-Dec-2018	<0.01	<0.001	0.203	<0.001	1.16	<0.0001	<0.001	0.002	0.008	<0.05	<0.001	0.035	<0.0001	0.008	0.006	<0.01	<0.001	0.012	<0.01	0.017
DW7068W	Tertiary	07-Jan-2019	0.02	<0.001	0.199	<0.001	1.15	<0.0001	<0.001	0.002	0.014	<0.05	<0.001	0.036	<0.0001	0.005	0.005	<0.01	<0.001	0.01	<0.01	0.086
DW7068W	Tertiary	18-Feb-2019	<0.01	<0.001	0.216	<0.001	1.37	<0.0001	<0.001	0.002	0.002	<0.05	<0.001	0.032	<0.0001	0.006	0.004	<0.01	0.001	0.011	<0.01	0.035
DW7068W	Tertiary	11-Mar-2019	<0.05	<0.005	0.186	<0.005	1.14	<0.0005	<0.005	<0.005	<0.005	<0.05	<0.005	0.025	<0.0001	<0.005	<0.005	<0.05	<0.005	0.009	<0.05	0.03
DW7068W	Tertiary	17-Apr-2019	<0.01	<0.001	0.192	<0.001	1.34	<0.0001	<0.001	0.002	<0.001	0.08	<0.001	0.038	<0.0001	0.005	0.006	<0.01	<0.001	0.01	<0.01	0.032
DW7068W	Tertiary	13-May-2019	<0.01	0.001	0.201	<0.001	1.26	<0.0001	<0.001	0.001	0.001	<0.05	<0.001	0.039	<0.0001	0.005	0.006	<0.01	<0.001	0.011	<0.01	0.047
DW7068W	Tertiary	11-Jul-2019	<0.05	<0.005	0.198	<0.005	1.52	<0.0005	<0.005	<0.005	<0.005	0.08	<0.005	0.059	<0.0001	0.006	0.012	<0.05	<0.005	0.01	<0.05	0.096
DW7076W	Alluvium	12-Dec-2018	0.02	0.002	0.181	<0.001	0.56	<0.0001	<0.001	0.003	0.006	0.09	<0.001	0.112	<0.0001	<0.001	0.004	<0.01	<0.001	0.01	<0.01	<0.005
DW7076W	Alluvium	07-Jan-2019	<0.01	0.002	0.278	<0.001	3.81	<0.0001	<0.001	0.004	0.011	<0.05	<0.001	0.118	<0.0001	0.004	0.004	<0.01	<0.001	0.058	0.01	0.007
DW7076W	Alluvium	18-Feb-2019	<0.01	0.002	0.344	<0.001	3.94	<0.0001	<0.001	0.002	0.019	0.12	<0.001	0.072	<0.0001	0.002	0.004	<0.01	<0.001	0.058	0.03	0.007
DW7076W	Alluvium	11-Mar-2019	<0.05	<0.005	0.26	<0.005	3.3	<0.0005	<0.005	<0.005	0.023	0.13	<0.005	0.075	<0.0001	<0.005	<0.005	<0.05	<0.005	0.051	<0.05	0.028
DW7076W	Alluvium	17-Apr-2019	<0.01	0.002	0.233	<0.001	3.62	<0.0001	<0.001	0.002	0.01	0.05	<0.001	0.059	<0.0001	0.002	0.003	<0.01	<0.001	0.034	0.01	0.012
DW7076W	Alluvium	13-May-2019	0.01	0.002	0.232	<0.001	4.03	<0.0001	<0.001	0.002	0.015	0.13	<0.001	0.063	<0.0001	0.002	0.002	<0.01	<0.001	0.053	0.01	0.01
DW7076W	Alluvium	19-Jun-2019	0.05	0.003	0.186	<0.001	3.69	<0.0001	<0.001	0.004	0.018	0.15	<0.001	0.09	<0.0001	0.002	0.006	<0.01	<0.001	0.058	0.02	0.025
DW7076W	Alluvium	11-Jul-2019	<0.05	<0.005	0.2	<0.005	4.56	<0.0005	<0.005	<0.005	0.009	<0.05	<0.005	0.064	<0.0001	<0.005	<0.005	<0.05	<0.005	0.041	<0.05	<0.025
DW7076W	Alluvium	26-Aug-2019	0.06	0.002	0.189	<0.001	3.98	<0.0001	<0.001	0.002	0.002	<0.05	<0.001	0.07	<0.0001	0.002	0.004	<0.01	<0.001	0.04	0.01	0.019
Alluvium	Count		9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	Count >LOR		4	7	9	0	9	0	0	7	9	6	0	9	0	6	7	0	0	9	6	7
	Min		0.01	0.002	0.181		0.56			0.002	0.002	0.05		0.059		0.002	0.002			0.01	0.01	0.007
	Max		0.06	0.003	0.344		4.56			0.004	0.023	0.15		0.118		0.004	0.006			0.058	0.03	0.028
	Mean		0.035	0.002	0.234		3.50			0.003	0.013	0.083		0.080		0.002	0.004			0.045	0.016	0.014
	Median		0.035	0.002	0.232		3.81			0.002	0.011	0.090		0.072		0.002	0.004			0.051	0.010	0.011
	StDev		0.024	0.0004	0.054		1.15			0.001	0.007	0.052		0.022		0.001	0.001			0.016	0.009	0.009

Appendix B2: Dissolved Metals/ Metalloid Data

Site	Groundwater Unit	Date	Al (diss)	As (diss)	Ba (diss)	Be (diss)	B (diss)	Cd (diss)	Cr (diss)	Co (diss)	Cu (diss)	Fe (diss)	Pb (diss)	Mn (diss)	Hg (diss)	Mo (diss)	Ni (diss)	Se (diss)	Ag (diss)	U (diss)	V (diss)	Zn (diss)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC 2000 - 95% Freshwater Species Protection			**0.055**	**0.013**			**0.37**	**0.0002**	**0.001**		**0.0014**		**0.0034**	**1.9**	**0.0006**		**0.011**	**0.011**	**0.00005**			**0.008**
Tertiary	Count		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	Count >LOR		1	1	7	0	7	0	0	5	4	2	0	7	0	6	6	0	1	7	0	7
	Min		0.02	0.001	0.186	0	1.14			0.001	0.001	0.08		0.025		0.005	0.004		0.001	0.009		0.017
	Max		0.02	0.001	0.216		1.52			0.002	0.014	0.08		0.059		0.008	0.012		0.001	0.012		0.096
	Mean				0.199		1.28			0.002	0.004			0.038		0.005	0.006			0.010		0.049
	Median				0.199		1.26			0.002	0.003			0.036		0.005	0.006			0.010		0.035
	StDev				0.009		0.14			0.001	0.005			0.010		0.002	0.003			0.001		0.030
Coal Seams	Count		45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
	Count >LOR		3	36	45	0	45	3	0	20	29	44	4	45	0	30	40	0	1	23	0	45
	Min		0.01	0.001	0.059	0	0.88	0.0001		0.001	0.001	0.08	0.002	0.087		0.001	0.002		0.007	0.001		0.025
	Max		0.02	0.029	0.477		1.49	0.0002		0.019	0.081	4.41	0.007	0.397		0.01	0.022		0.007	0.016		0.21
	Mean*			0.007	0.117		1.23			0.003	0.011	2.59	0.004	0.229		0.003	0.006			0.003		0.086
	Median*			0.003	0.103		1.25			0.002	0.003	2.45	0.004	0.240		0.002	0.005			0.003		0.075
	Standard Deviation*			0.007	0.073		0.14			0.004	0.018	1.20	0.002	0.086		0.002	0.005			0.003		0.039

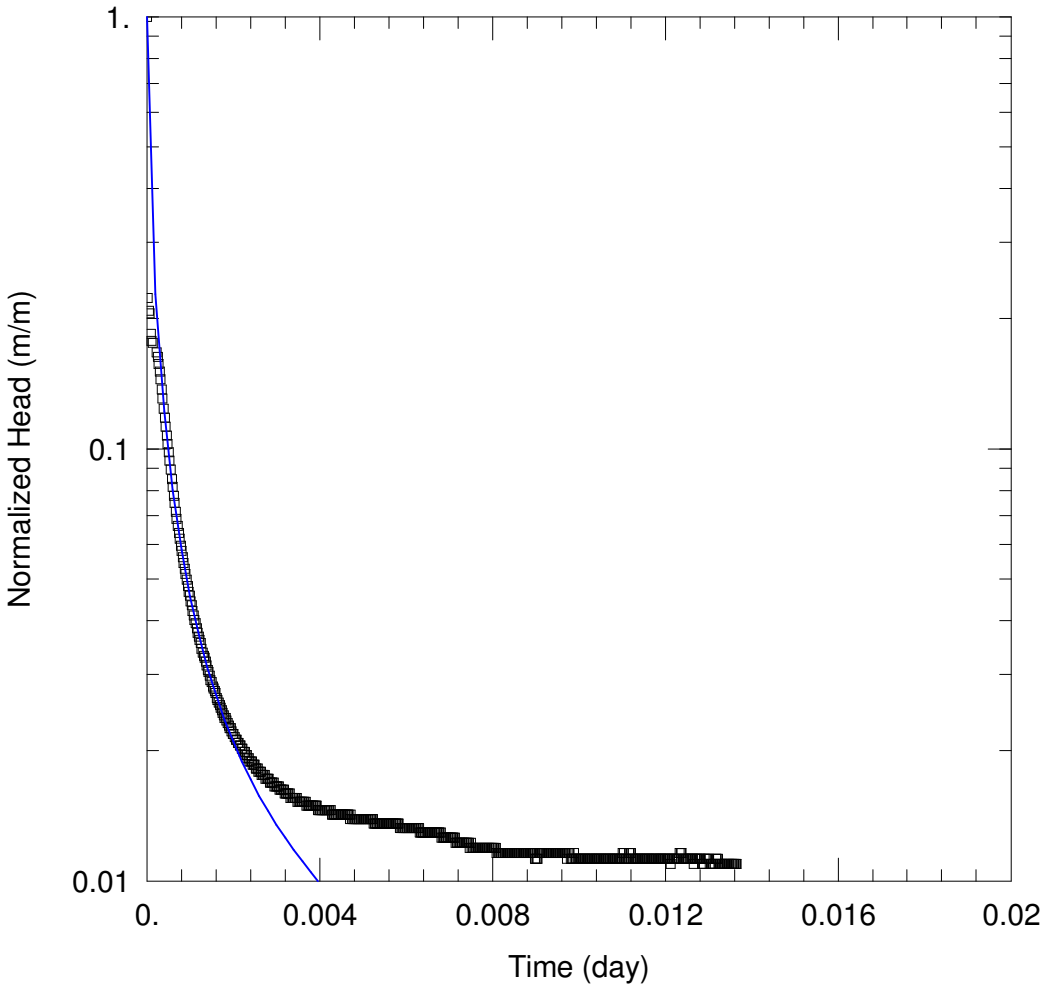
* For the purpose of statistical analysis, samples <LOR were converted to 0.5 x the LOR value

Appendix B3: Total Metals/ Metalloid Data

Site	Groundwater Unit	Date	Al (tot)	As (tot)	Ba (tot)	Be (tot)	B (tot)	Cd (tot)	Cr (tot)	Co (tot)	Cu (tot)	Fe (tot)	Pb (tot)	Mn (tot)	Hg (tot)	Mo (tot)	Ni (tot)	Se (tot)	Ag (tot)	U (tot)	V (tot)	Zn (tot)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
DW7065W	AR3	12-Dec-2018	0.33	0.022	0.082	<0.001	1.33	0.0002	<0.001	0.018	0.102	2.82	0.012	0.316	<0.0001	0.001	0.022	<0.01	<0.001	0.013	<0.01	0.19
DW7065W	AR3	07-Jan-2019	0.1	0.033	0.204	<0.001	1.58	0.0002	<0.001	0.012	0.057	3.24	0.002	0.264	<0.0001	0.003	0.015	<0.01	<0.001	0.011	<0.01	0.204
DW7065W	AR3	18-Feb-2019	0.11	0.025	0.12	<0.001	1.29	0.0002	<0.001	0.009	0.03	4.66	<0.001	0.238	<0.0001	0.001	0.016	<0.01	<0.001	0.007	<0.01	0.124
DW7065W	AR3	11-Mar-2019	0.28	0.017	0.094	<0.005	1.64	<0.0005	<0.005	0.01	0.045	5.39	<0.005	0.362	<0.0001	<0.005	0.014	<0.05	<0.005	0.006	<0.05	0.09
DW7065W	AR3	17-Apr-2019	0.06	0.017	0.106	<0.001	1.13	<0.0001	<0.001	0.006	0.031	3.37	<0.001	0.231	<0.0005	0.001	0.008	<0.01	<0.001	0.007	<0.01	0.1
DW7065W	AR3	13-May-2019	0.06	0.022	0.32	<0.001	1.37	<0.0001	<0.001	0.008	0.039	4.15	<0.001	0.35	<0.0001	0.001	0.014	<0.01	<0.001	0.008	<0.01	0.149
DW7065W	AR3	19-Jun-2019	0.04	0.018	0.178	<0.001	1.14	<0.0001	<0.001	0.006	0.006	3.87	<0.001	0.295	<0.0001	<0.001	0.011	<0.01	<0.001	0.008	<0.01	0.103
DW7065W	AR3	11-Jul-2019	0.12	0.008	0.284	<0.005	1.47	<0.0005	<0.005	0.006	0.01	2.12	<0.005	0.406	<0.0001	<0.005	0.011	<0.05	<0.005	0.006	<0.05	0.121
DW7065W	AR3	26-Aug-2019	0.17	0.019	0.474	<0.001	1.52	<0.0001	<0.001	0.006	0.008	4.39	0.001	0.279	<0.0001	<0.001	0.01	<0.01	<0.001	0.009	<0.01	0.42
DW7067W	AR3	12-Dec-2018	0.06	0.006	0.059	<0.001	1.44	<0.0001	<0.001	0.005	0.046	2.32	0.005	0.11	<0.0001	0.001	0.006	<0.01	<0.001	0.004	<0.01	0.111
DW7067W	AR3	07-Jan-2019	<0.05	0.012	0.089	<0.005	1.47	<0.0005	<0.005	<0.005	0.027	3.23	<0.005	0.122	<0.0001	<0.005	0.006	<0.05	<0.005	<0.005	<0.05	0.149
DW7067W	AR3	18-Feb-2019	0.01	0.013	0.077	<0.001	1.36	<0.0001	<0.001	0.002	0.021	4.31	<0.001	0.112	<0.0001	0.002	0.007	0.01	<0.001	0.002	<0.01	0.067
DW7067W	AR3	11-Mar-2019	<0.05	0.01	0.079	<0.005	1.76	<0.0005	<0.005	<0.005	0.014	3.88	<0.005	0.119	<0.0001	<0.005	<0.005	<0.05	<0.005	<0.005	<0.05	0.09
DW7067W	AR3	17-Apr-2019	0.02	0.008	0.069	<0.001	1.19	<0.0001	<0.001	0.001	0.012	3.38	<0.001	0.102	<0.0001	<0.001	0.002	<0.01	<0.001	0.002	<0.01	0.063
DW7067W	AR3	13-May-2019	0.01	0.008	0.156	<0.001	1.44	<0.0001	<0.001	0.001	0.022	3.34	<0.001	0.121	<0.0001	<0.001	0.006	<0.01	<0.001	0.002	<0.01	0.098
DW7067W	AR3	19-Jun-2019	0.02	0.004	0.11	<0.001	1.24	<0.0001	<0.001	0.002	0.007	0.52	<0.001	0.092	<0.0001	<0.001	0.006	<0.01	<0.001	0.002	<0.01	0.092
DW7067W	AR3	11-Jul-2019	<0.05	<0.005	0.134	<0.005	1.5	<0.0005	<0.005	<0.005	0.013	2.35	<0.005	0.154	<0.0001	<0.005	0.008	<0.05	<0.005	<0.005	<0.05	0.148
DW7067W	AR3	26-Aug-2019	0.04	0.007	0.184	<0.001	1.6	<0.0001	<0.001	0.001	0.007	2.98	<0.001	0.107	<0.0001	<0.001	0.006	<0.01	<0.001	0.002	<0.01	0.06
DW7068W	Tertiary	12-Dec-2018	1.27	<0.001	0.186	<0.001	1.26	<0.0001	0.004	0.002	0.004	0.53	0.001	0.036	<0.0001	0.007	0.005	<0.01	<0.001	0.011	<0.01	0.019
DW7068W	Tertiary	07-Jan-2019	1.82	<0.001	0.268	<0.001	1.48	0.0002	0.006	0.002	0.017	0.91	0.002	0.044	<0.0001	0.007	0.006	<0.01	<0.001	0.012	<0.01	0.106
DW7068W	Tertiary	18-Feb-2019	4.11	0.002	0.234	<0.001	1.3	<0.0001	0.013	0.002	0.01	2.2	0.003	0.045	<0.0001	0.005	0.006	<0.01	<0.001	0.009	0.02	0.067
DW7068W	Tertiary	11-Mar-2019	3.12	<0.005	0.214	<0.005	1.48	<0.0005	0.009	<0.005	0.007	1.5	<0.005	0.033	<0.0001	<0.005	0.006	<0.05	<0.005	0.012	<0.05	<0.026
DW7068W	Tertiary	17-Apr-2019	2.43	<0.001	0.237	<0.001	1.16	<0.0001	0.008	0.002	0.008	1.55	0.002	0.041	<0.0001	0.005	0.006	<0.01	<0.001	0.01	<0.01	0.043
DW7068W	Tertiary	13-May-2019	2.81	0.002	0.242	<0.001	1.4	<0.0001	0.01	0.002	0.028	2	0.003	0.054	<0.0001	0.005	0.009	<0.01	<0.001	0.011	<0.01	0.094
DW7068W	Tertiary	11-Jul-2019	3.9	<0.005	0.22	<0.005	1.55	<0.0005	0.009	<0.005	0.007	1.24	<0.005	0.063	<0.0001	0.006	0.014	<0.05	<0.005	0.01	<0.05	0.126
DW7069W	Castor Lower/Pollux Upper	12-Dec-2018	0.1	0.003	0.056	<0.001	1.37	0.0001	<0.001	0.002	0.06	2.4	0.005	0.174	<0.0001	0.001	0.004	<0.01	<0.001	0.002	<0.01	0.137
DW7069W	Castor Lower/Pollux Upper	07-Jan-2019	0.07	0.004	0.083	<0.001	1.41	0.0001	<0.001	<0.001	0.028	2.86	0.001	0.184	<0.0001	0.002	0.003	<0.01	<0.001	0.002	<0.01	0.144
DW7069W	Castor Lower/Pollux Upper	18-Feb-2019	0.09	0.003	0.072	<0.001	1.31	<0.0001	<0.001	<0.001	0.02	2.4	<0.001	0.158	<0.0001	0.002	0.005	<0.01	<0.001	<0.001	<0.01	0.089
DW7069W	Castor Lower/Pollux Upper	11-Mar-2019	0.08	<0.005	0.069	<0.005	1.73	<0.0005	<0.005	<0.005	0.014	2.48	<0.005	0.188	<0.0001	<0.005	<0.005	<0.05	<0.005	<0.005	<0.05	0.088
DW7069W	Castor Lower/Pollux Upper	17-Apr-2019	0.04	0.002	0.064	<0.001	1.14	<0.0001	<0.001	<0.001	0.01	2.42	<0.001	0.154	<0.0001	<0.001	0.002	<0.01	<0.001	<0.001	<0.01	0.064
DW7069W	Castor Lower/Pollux Upper	13-May-2019	0.03	0.004	0.117	<0.001	1.41	0.0002	<0.001	<0.001	0.02	2.64	<0.001	0.185	<0.0001	0.001	0.005	<0.01	<0.001	<0.001	<0.01	0.082
DW7069W	Castor Lower/Pollux Upper	19-Jun-2019	0.02	0.002	0.084	<0.001	1.21	<0.0001	<0.001	<0.001	0.014	2.38	<0.001	0.153	<0.0001	<0.001	0.003	<0.01	<0.001	<0.001	<0.01	0.104
DW7069W	Castor Lower/Pollux Upper	11-Jul-2019	0.13	<0.005	0.087	<0.005	1.5	<0.0005	<0.005	<0.005	0.012	2.05	<0.005	0.168	<0.0001	<0.005	0.008	<0.05	<0.005	<0.005	<0.05	0.133
DW7069W	Castor Lower/Pollux Upper	26-Aug-2019	0.12	0.003	0.113	<0.001	1.56	<0.0001	<0.001	<0.001	0.006	2.57	<0.001	0.147	<0.0001	0.001	0.004	<0.01	<0.001	<0.001	<0.01	0.045
DW7073W	Castor Lower/Pollux Upper	13-Dec-2018	0.3	0.001	0.108	<0.001	1.14	<0.0001	<0.001	<0.001	0.05	3.61	0.005	0.288	<0.0001	0.002	0.002	<0.01	<0.001	<0.001	<0.01	0.097
DW7073W	Castor Lower/Pollux Upper	07-Jan-2019	0.64	0.001	0.149	<0.001	1.26	0.0001	<0.001	<0.001	0.02	4.59	0.003	0.36	<0.0001	0.003	0.002	<0.01	<0.001	<0.001	<0.01	0.115
DW7073W	Castor Lower/Pollux Upper	18-Feb-2019	0.23	0.002	0.129	<0.001	1.08	0.0001	<0.001	<0.001	0.017	4.16	<0.001	0.35	<0.0001	0.002	0.005	<0.01	<0.001	<0.001	<0.01	0.104
DW7073W	Castor Lower/Pollux Upper	11-Mar-2019	0.23	<0.005	0.142	<0.005	1.39	<0.0005	<0.005	<0.005	0.011	5.2	<0.005	0.405	<0.0001	<0.005	<0.005	<0.05	<0.005	<0.005	<0.05	0.097
DW7073W	Castor Lower/Pollux Upper	17-Apr-2019	0.18	0.001	0.115	<0.001	0.94	<0.0001	<0.001	<0.001	0.009	4.31	<0.001	0.318	<0.0001	0.002	0.002	<0.01	<0.001	<0.001	<0.01	0.055
DW7073W	Castor Lower/Pollux Upper	13-May-2019	0.27	0.003	0.167	<0.001	1.1	<0.0001	<0.001	<0.001	0.015	4.66	<0.001	0.345	<0.0001	0.002	0.003	<0.01	<0.001	<0.001	<0.01	0.054
DW7073W	Castor Lower/Pollux Upper	19-Jun-2019	0.15	0.002	0.128	<0.001	1.02	<0.0001	<0.001	<0.001	0.015	4.2	<0.001	0.325	<0.0001	0.002	0.002	<0.01	<0.001	<0.001	<0.01	0.065
DW7073W	Castor Lower/Pollux Upper	11-Jul-2019	0.22	<0.005	0.133	<0.005	1.2	<0.0005	<0.005	<0.005	0.011	3.83	<0.005	0.347	<0.0001	<0.005	0.006	<0.05	<0.005	<0.005	<0.05	0.116
DW7073W	Castor Lower/Pollux Upper	26-Aug-2019	0.23	0.001	0.14	<0.001	1.21	<0.0001	<0.001	<0.001	0.006	4.01	<0.001	0.301	<0.0001	0.002	0.003	<0.01	<0.001	<0.001	<0.01	0.037
DW7074W	Castor Upper	13-Dec-2018	0.05	0.001	0.073	<0.001	1.45	<0.0001	<0.001	0.001	0.034	0.09	0.003	0.203	<0.0001	0.009	0.003	<0.01	<0.001	0.002	<0.01	0.078
DW7074W	Castor Upper	07-Jan-2019	0.03	0.001	0.112	<0.001	1.52	0.0001	<0.001	0.002	0.016	0.22	0.001	0.274	<0.0001	0.012	0.003	<0.01	<0.001	0.003	<0.01	0.082
DW7074W	Castor Upper	18-Feb-2019	0.02	0.003	0.087	<0.001	1.34	<0.0001	<0.001	0.002	0.019	0.43	<0.001	0.26	<0.0001	0.008	0.005	<0.01	<0.001	0.002	<0.01	0.071
DW7074W	Castor Upper	11-Mar-2019	<0.05	<0.005	0.084	<0.005	1.64	<0.0005	<0.005	<0.005	0.012	1.63	<0.005	0.264	<0.0001	0.007	<0.005	<0.05	<0.005	<0.005	<0.05	<0.026
DW7074W	Castor Upper	17-Apr-2019	0.03	0.005	0.078	<0.001	1.18	<0.0001	<0.001	<0.001	0.008	1.86	<0.001	0.227	<0.0001	0.006	0.003	<0.01	<0.001	0.002	<0.01	0.043
DW7074W	Castor Upper	13-May-2019	0.06	0.006	0.117	<0.001	1.45	<0.0001	<0.001	<0.001	0.016	2.77	<0.001	0.27	<0.0001	0.005	0.005	<0.01	<0.001	0.003	<0.01	0.054
DW7074W	Castor Upper	19-Jun-2019	0.02	0.004	0.088	<0.001	1.27	<0.0001	<0.001	<0.001	0.014	1.87	<0.001	0.227	<0.0001	0.005	0.004	<0.01	<0.001	0.002	<0.01	0.059
DW7074W	Castor Upper	11-Jul-2019	0.07	<0.005	0.1	<0.005	1.53	<0.0005	<0.005	<0.005	0.006	1.11	<0.005	0.256	<0.0001	<0.005	0.008	<0.05	<0.005	<0.005	<0.05	0.068
DW7074W	Castor Upper	26-Aug-2019	0.21	0.003	0.119	<0.001	1.52	<0.0001	<0.001	<0.001	0.008	2.01	<0.001	0.245	<0.0001	0.004	0.005	<0.01	<0.001	0.002	<0.01	0.04
DW7076W	Alluvium	12-Dec-2018	2.06	0.002	0.301	<0.001	3.87	<0.0001	0.001	0.005	0.002	0.89	0.001	0.17	<0.0001	0.002	0.005	<0.01	<0.001	0.062	<0.01	0.009
DW7076W	Alluvium	07-Jan-2019	7.22	0.003	0.389	<0.001	4.43	<0.0001	0.011	0.007	0.098	2.93	0.005	0.291	<0.0001	0.004	0.007	<0.01	<0.001	0.073	0.04	0.05
DW7076W	Alluvium	18-Feb-2019	2.86	0.002	0.352	<0.001	3.56	<0.0001	0.006	0.004	0.103	1.28	0.002	0.154	<0.0001	0.003	0.005	<0.01	<0.001	0.053	0.04	0.024
DW7076W	Alluvium	11-Mar-2019	6.6	<0.005	0.331	<0.005	4.71	<0.0005	0.009	0.006	0.308	2.52	0.006	0.236	<0.0001	<0.005	0.006	<0.05	<0.005	0.065	<0.05	<0.026
DW7076W	Alluvium	17-Apr-2019	3.88	0.002	0.31	<0.001	3.41	<0.0001	0.008	0.004	0.164	1.92	0.003	0.158	<0.0001	0.002	0.004	<0.01	<0.001	0.053	0.02	0.041
DW7076W	Alluvium	13-May-2019	4.8	0.003	0.27	<0.001	4.2	0.0001	0.007	0.004	0.313	2.22	0.003	0.176	<0.0001	0.002	0.004	<0.01	<0.001	0.055	0.02	0.036
DW7076W	Alluvium	19-Jun-2019	2.05	0.002	0.209	<0.001	3.82	<0.0001	0.005	0.004	0.232	1.24	0.002	0.144	<0.0001	0.002	0.005	<0.01	<0.001	0.05	0.02	0.035
DW7076W		11-Jul-2019	4.96	<0.005	0.224	<0.005	4.61	<0.0005	0.006	<0.005	0.452	2.2	<0.005	0.154	<0.0001	<0.005	0.007	<0.05	<0.005	0.044	<0.05	0.058
DW7076W	Alluvium	26-Aug-2019	20.1	0.004	0.318	0.004	4.57	<0.0001	0.02	0.008	0.37	6.91	0.02	0.29	<0.0001	0.001	0.013	<0.01	<0.001	0.046	0.04	0.124

APPENDIX C

SLUG TEST ANALYSIS SHEETS



WELL TEST ANALYSIS

Data Set: D:\...\DW7033W1_KGS Model.aqt
Date: 09/07/19 Time: 15:12:19

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7033W1
Test Date: 17 July 2019

AQUIFER DATA

Saturated Thickness: 14.81 m

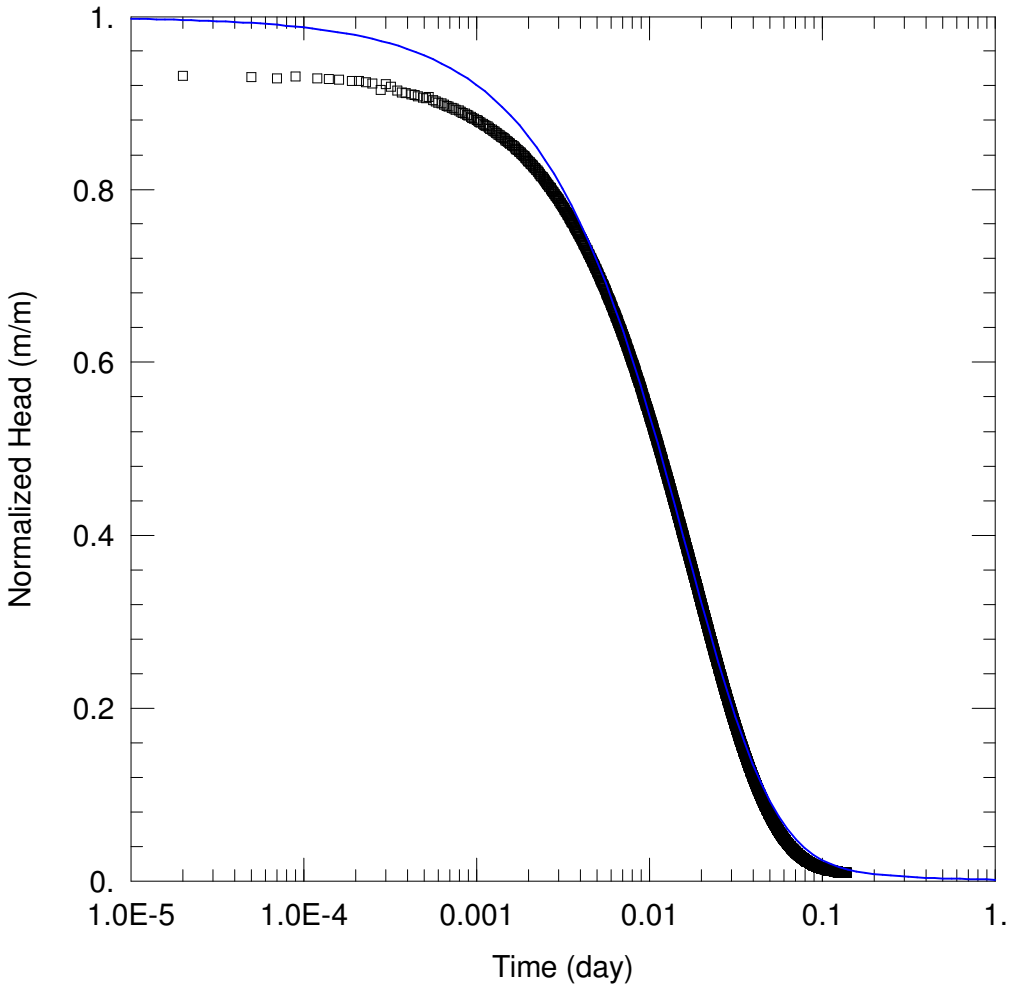
WELL DATA (DW7033W1)

Initial Displacement: 30.18 m
Total Well Penetration Depth: 14.81 m
Casing Radius: 0.025 m
Static Water Column Height: 14.81 m
Screen Length: 6. m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 0.7028 m/day
Kz/Kr = 0.1
Ss = 0.02476 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7033W2_KGS Model.aqt
Date: 09/07/19 Time: 15:14:31

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7033W2
Test Date: 17 July 2019

AQUIFER DATA

Saturated Thickness: 2. m

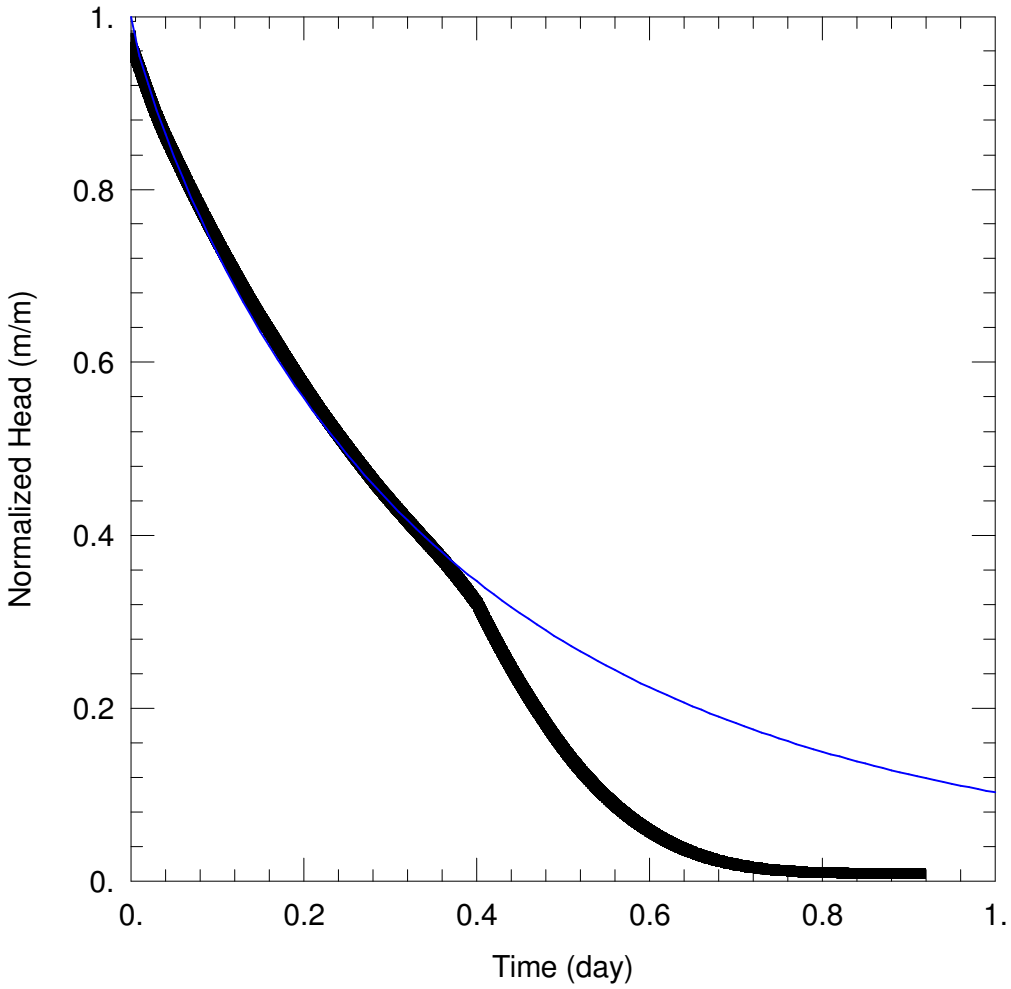
WELL DATA (DW7033W2)

Initial Displacement: 29.22 m
Total Well Penetration Depth: 45.28 m
Casing Radius: 0.025 m
Static Water Column Height: 45.28 m
Screen Length: 1.5 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.06068 m/day
Kz/Kr = 1.
Ss = 0.0002924 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7033W3_KGS Model.aqt
Date: 09/07/19 Time: 17:55:00

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7033W3
Test Date: 17 July 2019

AQUIFER DATA

Saturated Thickness: 6.7 m

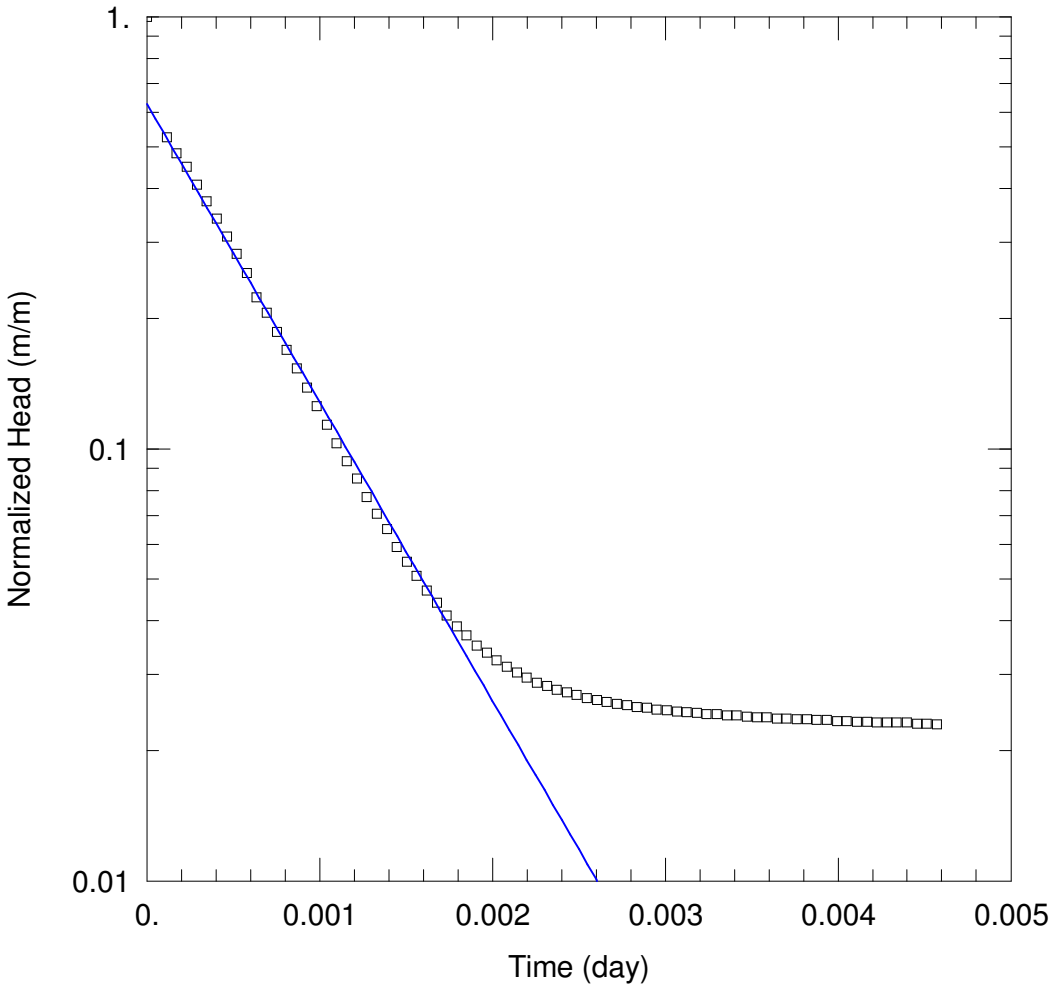
WELL DATA (DW7033W3)

Initial Displacement: 29.17 m
Total Well Penetration Depth: 51.83 m
Casing Radius: 0.025 m
Static Water Column Height: 51.83 m
Screen Length: 1.5 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.002308 m/day
Kz/Kr = 0.1
Ss = 0.0002924 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7035W3_Bouwer-Rice.aqt
Date: 09/07/19 Time: 15:25:54

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7035W3
Test Date: 16 July 2019

AQUIFER DATA

Saturated Thickness: 2. m Anisotropy Ratio (Kz/Kr): 1.

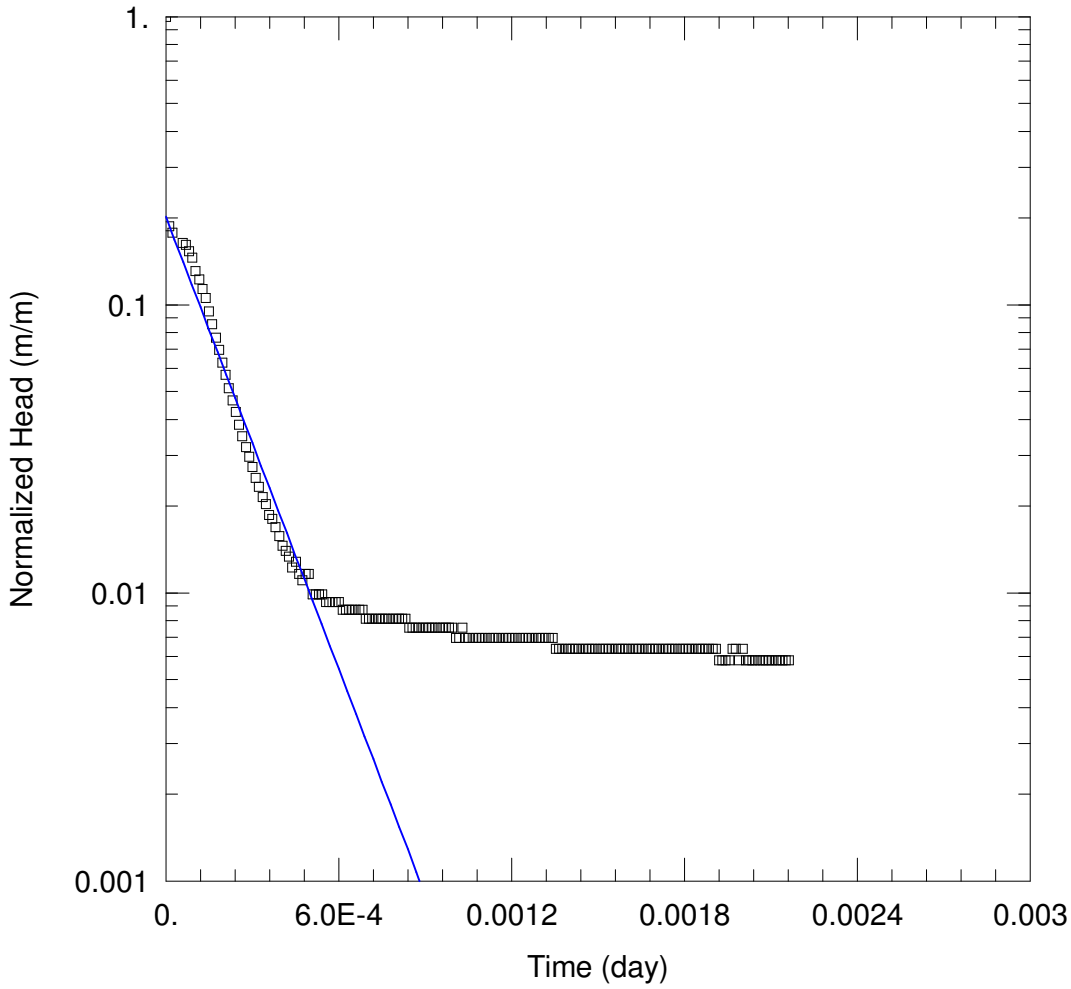
WELL DATA (DW7035W3)

Initial Displacement: 22.01 m Static Water Column Height: 26.43 m
Total Well Penetration Depth: 26.43 m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 1.593 m/day y0 = 13.82 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7082W1_Bouwer-Rice.aqt
Date: 09/07/19 Time: 15:24:28

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7082W1
Test Date: 22 August 2019

AQUIFER DATA

Saturated Thickness: 2. m Anisotropy Ratio (Kz/Kr): 1.

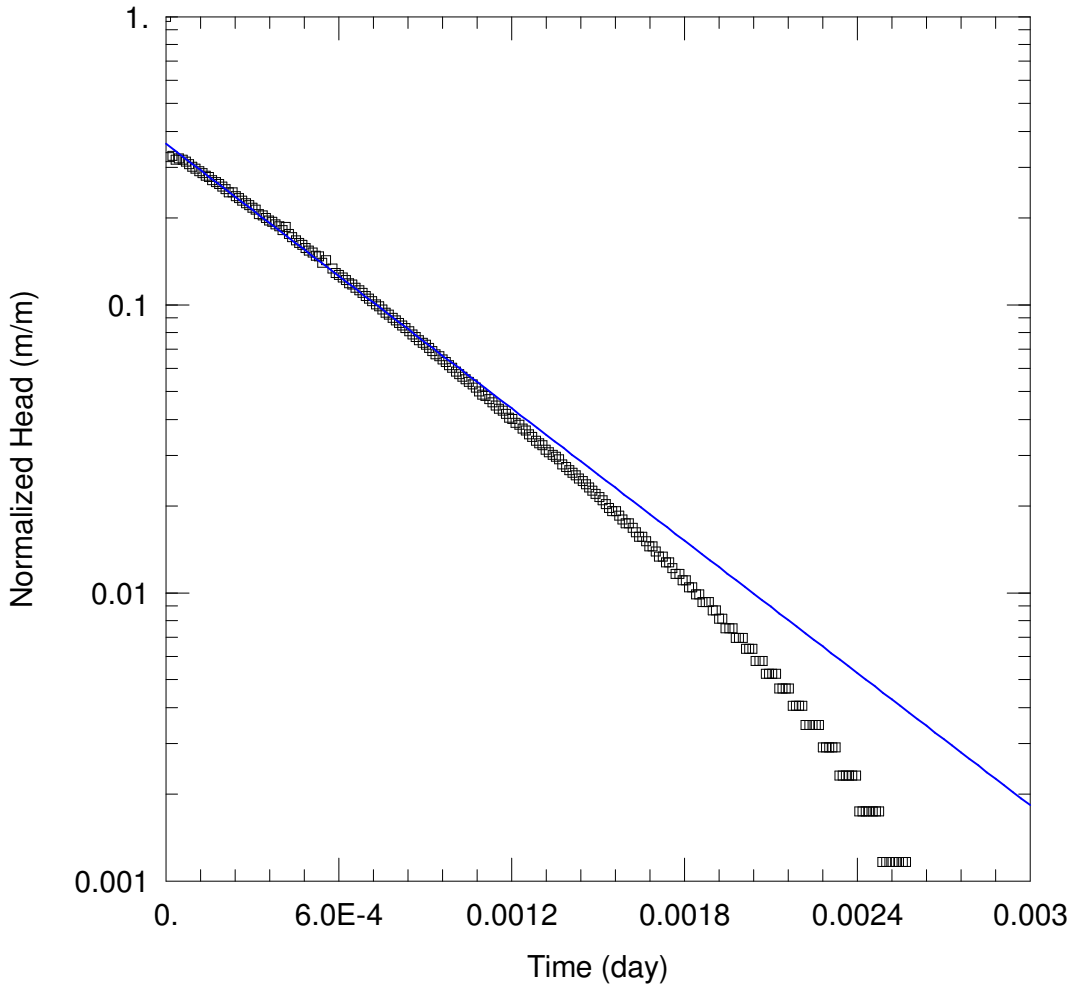
WELL DATA (DW7082W1)

Initial Displacement: 17.19 m Static Water Column Height: 23.39 m
Total Well Penetration Depth: 23.39 m Screen Length: 1.67 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 5.387 m/day y0 = 3.468 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7082W2_Bouwer-Rice.aqt
Date: 09/07/19 Time: 15:30:14

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7082W2
Test Date: 22 August 2019

AQUIFER DATA

Saturated Thickness: 2. m Anisotropy Ratio (Kz/Kr): 1.

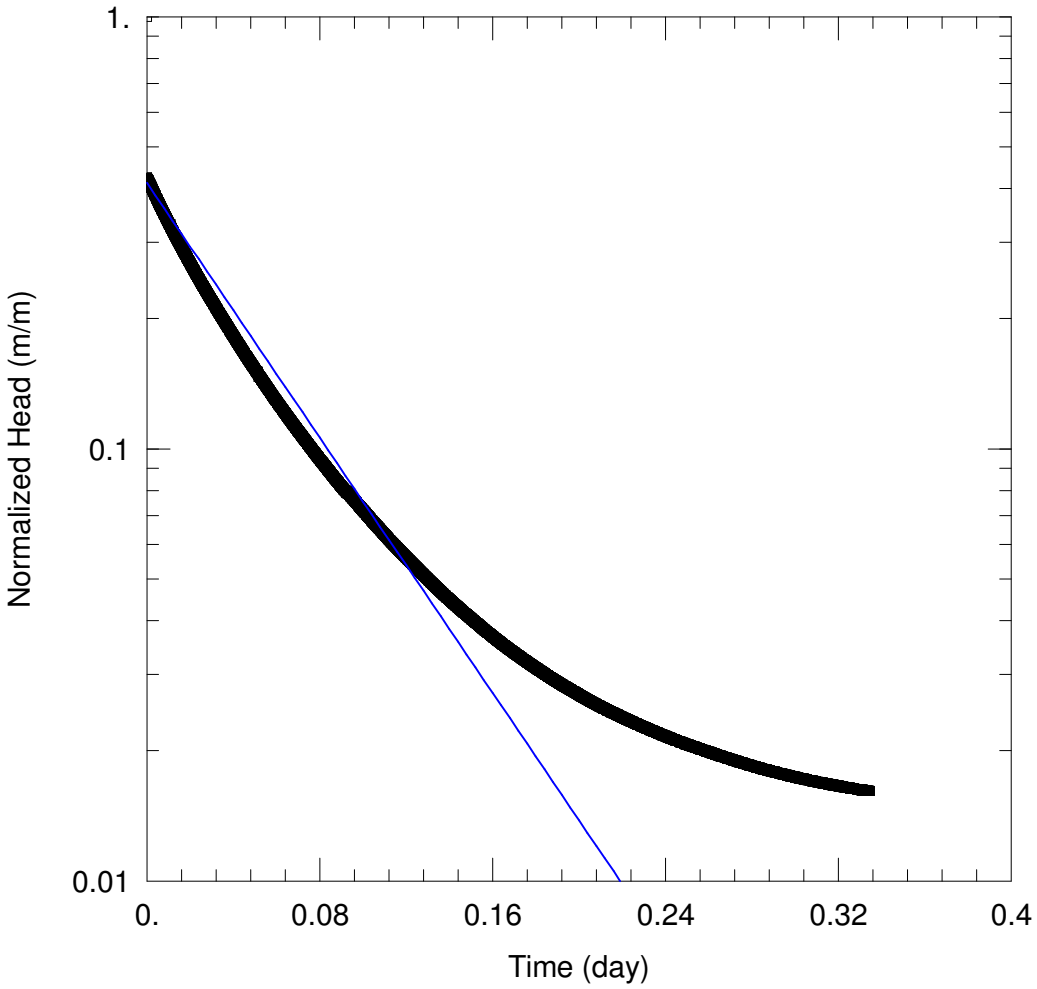
WELL DATA (DW7082W2)

Initial Displacement: 17.23 m Static Water Column Height: 41.94 m
Total Well Penetration Depth: 41.94 m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 1.855 m/day y0 = 6.243 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7093W1_Bouwer-Rice.aqt
Date: 09/07/19 Time: 15:36:35

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7092W1
Test Date: 2 September 2019

AQUIFER DATA

Saturated Thickness: 2. m Anisotropy Ratio (Kz/Kr): 0.1

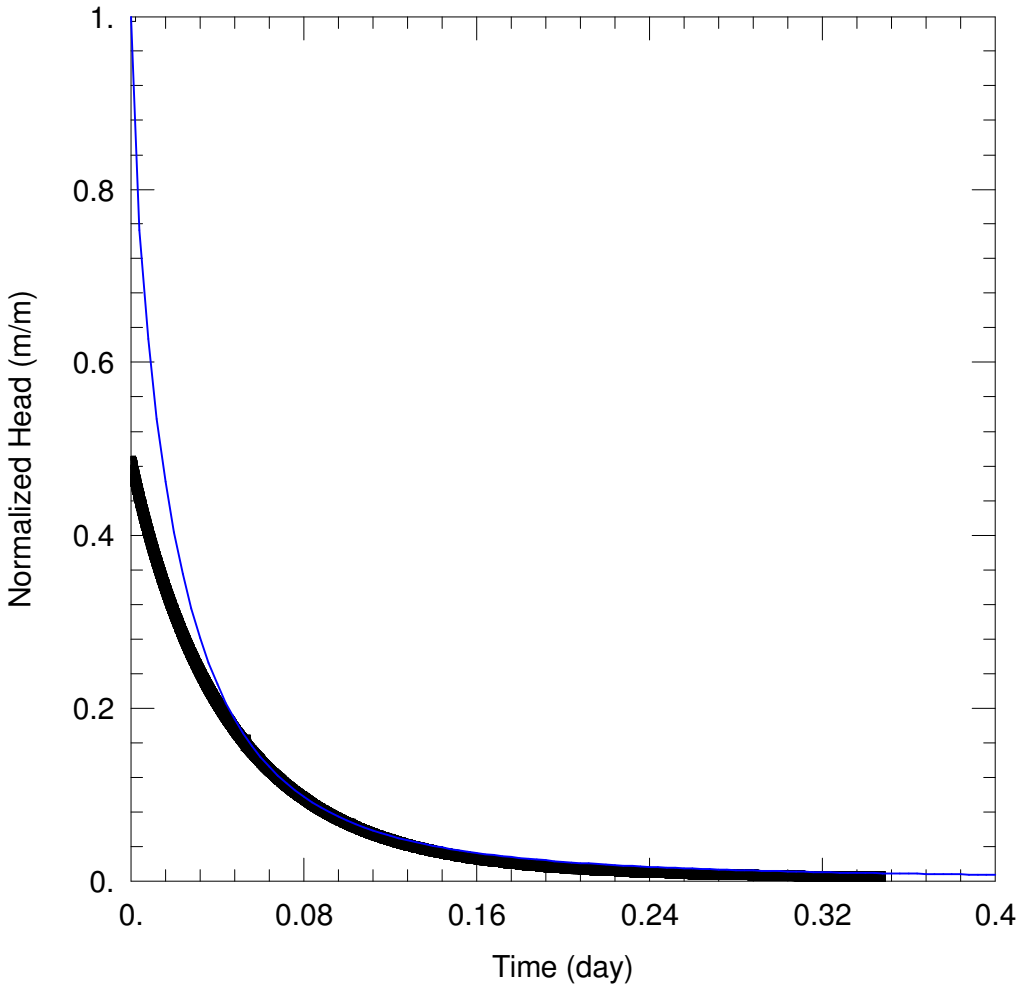
WELL DATA (DW7093W1)

Initial Displacement: 28.78 m Static Water Column Height: 58.52 m
Total Well Penetration Depth: 58.52 m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.02229 m/day y0 = 11.88 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7093W3_KGS Model.aqt
Date: 09/07/19 Time: 15:40:14

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7092W3
Test Date: 2 September 2019

AQUIFER DATA

Saturated Thickness: 2. m

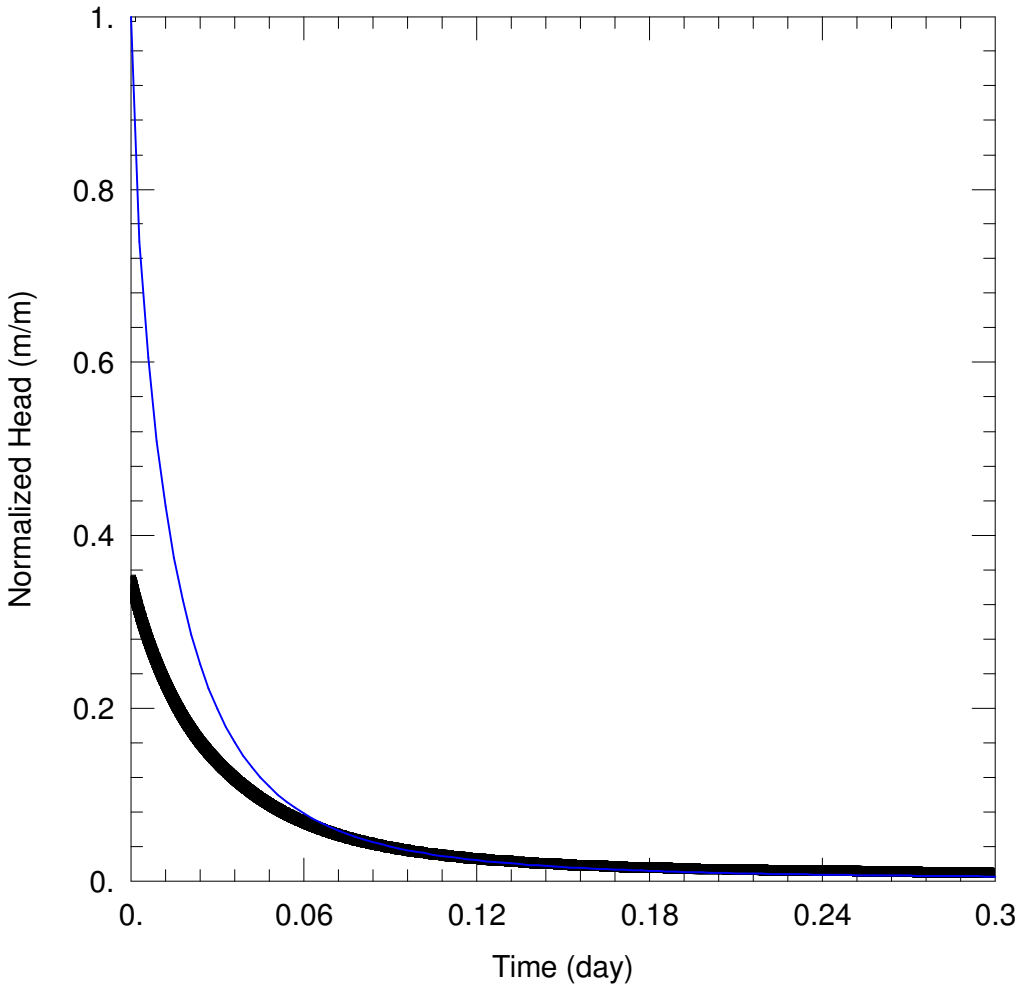
WELL DATA (DW7093W3)

Initial Displacement: 28.71 m
Total Well Penetration Depth: 94.54 m
Casing Radius: 0.025 m
Static Water Column Height: 94.54 m
Screen Length: 1.5 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.03877 m/day
Kz/Kr = 1.
Ss = 0.01774 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7105W2_KGS Model.aqt
Date: 09/07/19 Time: 15:47:39

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7105W2
Test Date: 22 August 2019

AQUIFER DATA

Saturated Thickness: 2. m

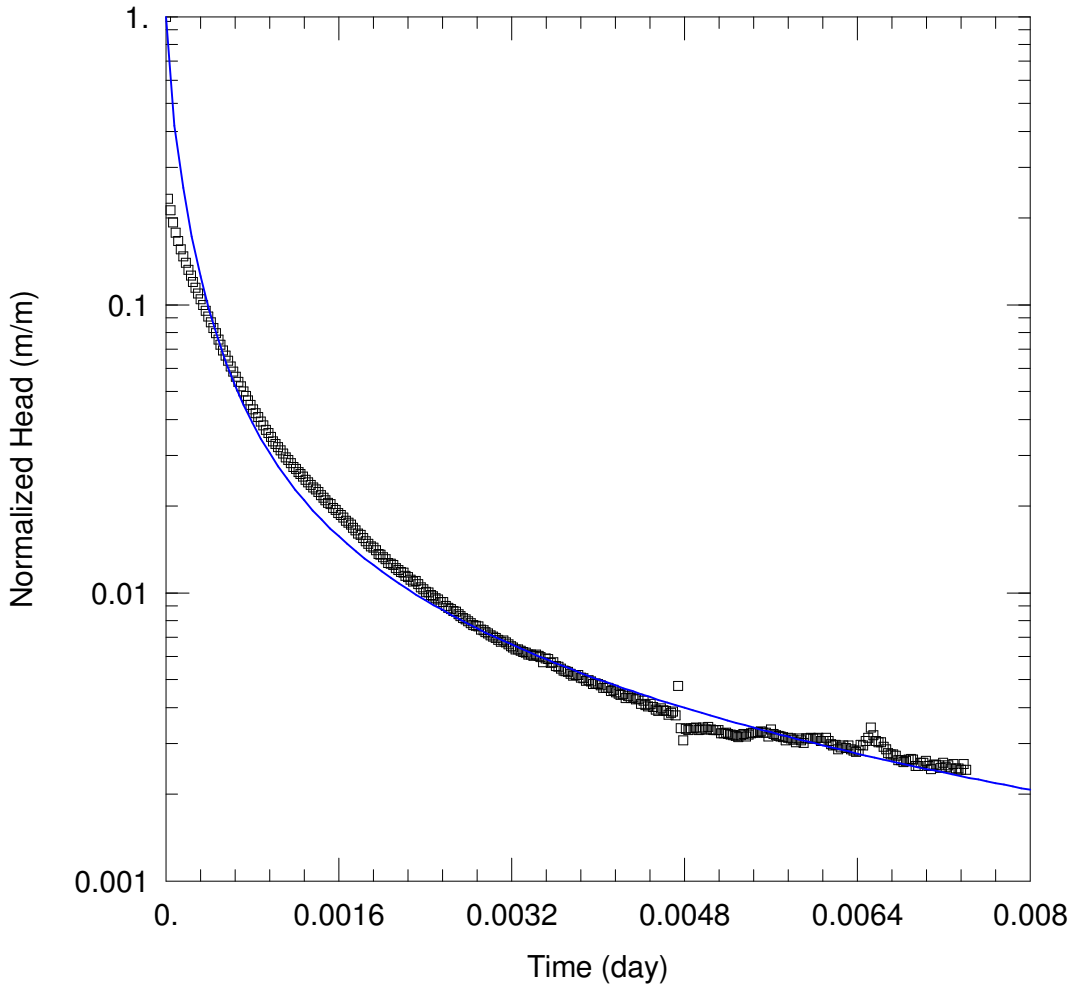
WELL DATA (DW7105W2)

Initial Displacement: 31.4 m
Total Well Penetration Depth: 32.8 m
Casing Radius: 0.025 m
Static Water Column Height: 32.8 m
Screen Length: 1.5 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.066 m/day
Kz/Kr = 1.
Ss = 0.01774 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7178W1_KGS Model.aqt
Date: 09/07/19 Time: 15:50:25

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7178W1
Test Date: 16 July 2019

AQUIFER DATA

Saturated Thickness: 23.39 m

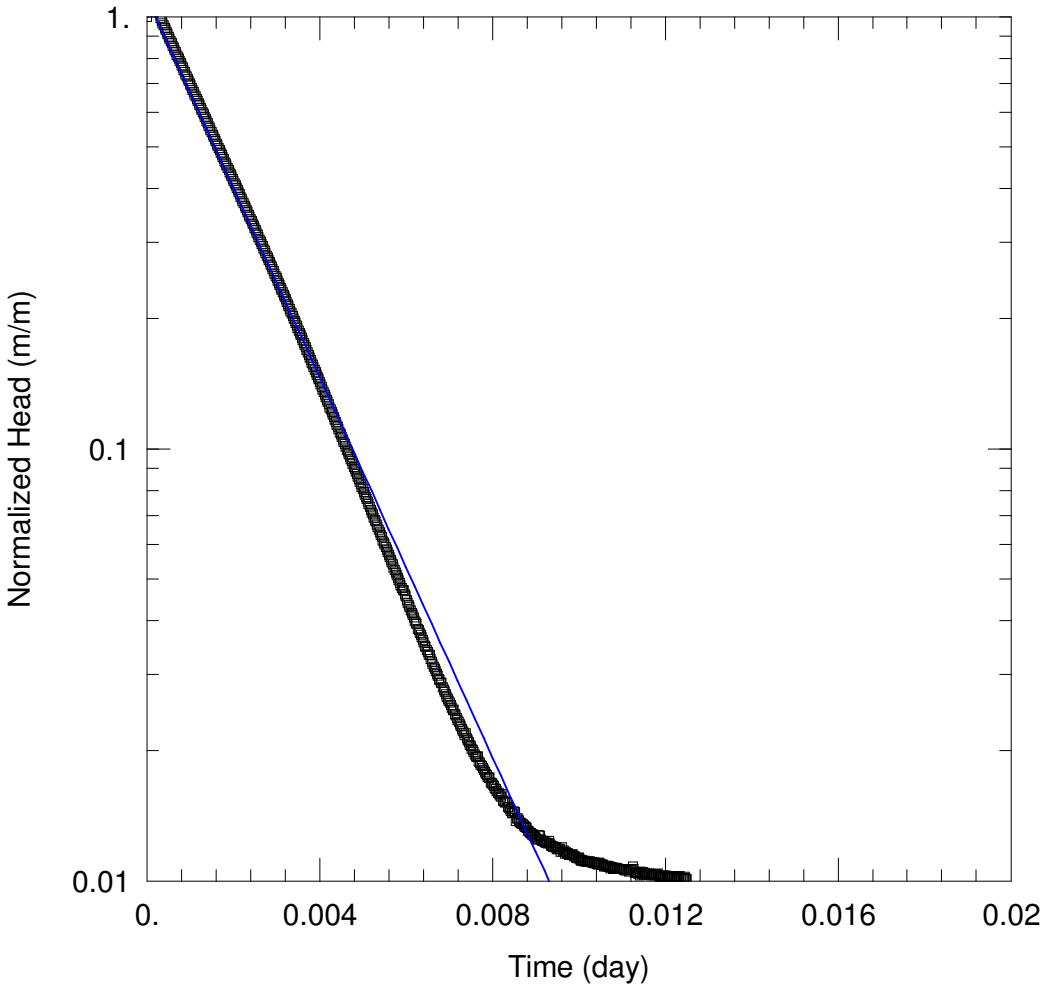
WELL DATA (DW7178W1)

Initial Displacement: 17.19 m
Total Well Penetration Depth: 23.42 m
Casing Radius: 0.025 m
Static Water Column Height: 23.39 m
Screen Length: 1.7 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 3.805 m/day
Kz/Kr = 1.
Ss = 0.02476 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7178W2_KGS Model.aqt
Date: 09/07/19 Time: 16:23:06

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7178W2
Test Date: 16 July 2019

AQUIFER DATA

Saturated Thickness: 3. m Anisotropy Ratio (Kz/Kr): 1.

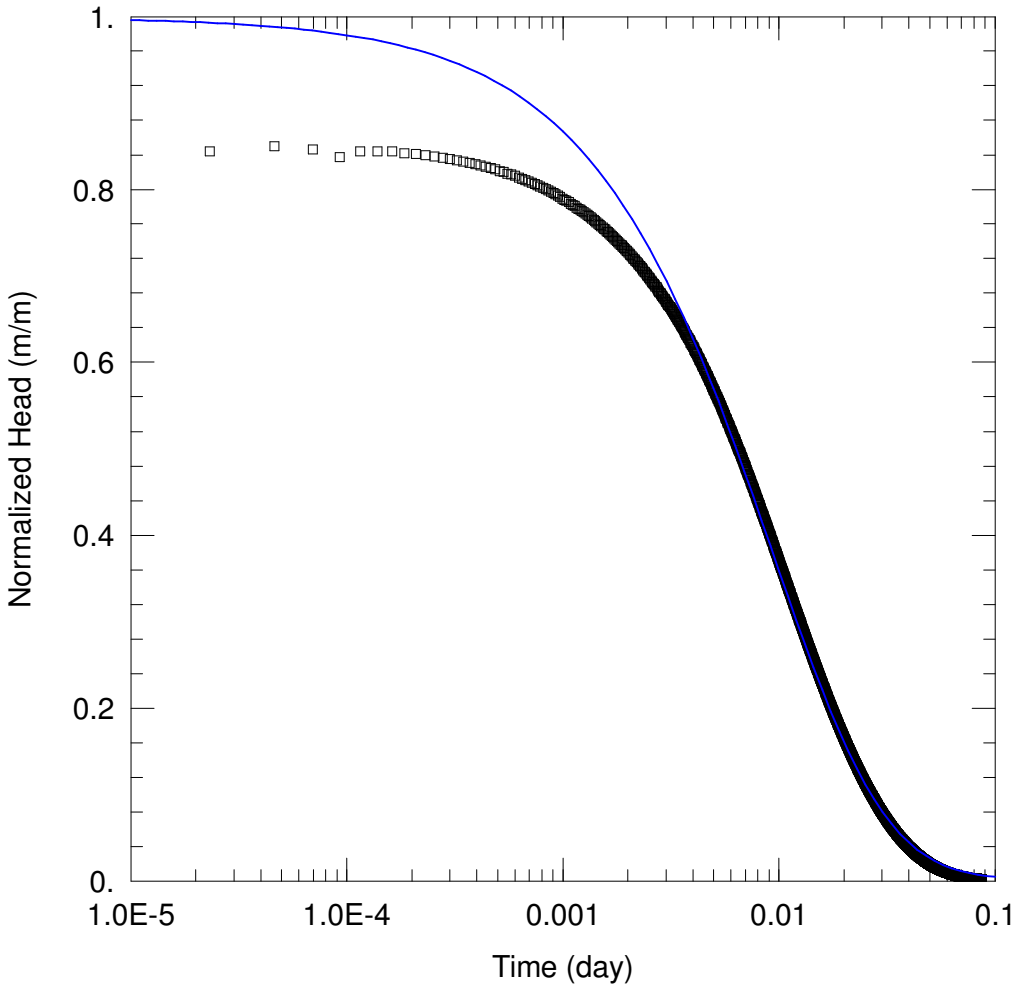
WELL DATA (DW7178W2)

Initial Displacement: 17.23 m Static Water Column Height: 41.94 m
Total Well Penetration Depth: 41.94 m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.5322 m/day y0 = 19.08 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7220W1_KGS Model.aqt
Date: 09/07/19 Time: 16:59:12

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7220W1
Test Date: 19 July 2019

AQUIFER DATA

Saturated Thickness: 10.88 m

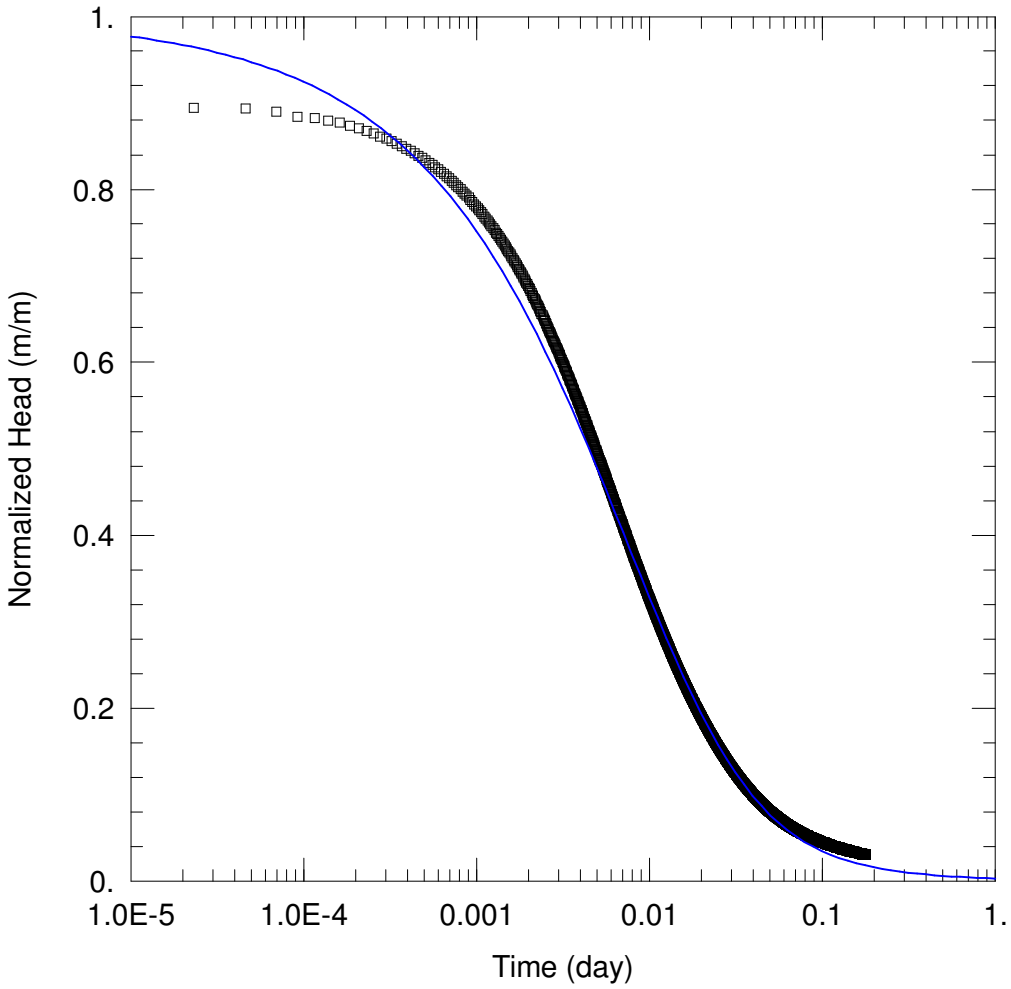
WELL DATA (DW7220W1)

Initial Displacement: 15.62 m
Total Well Penetration Depth: 10.88 m
Casing Radius: 0.025 m
Static Water Column Height: 10.88 m
Screen Length: 3. m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: KGS Model

Kr = 0.04546 m/day
Kz/Kr = 1.
Ss = 0.0001408 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7220W2_KGS Model.aqt
Date: 09/07/19 Time: 17:03:33

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7220W2
Test Date: 19 July 2019

AQUIFER DATA

Saturated Thickness: 6. m

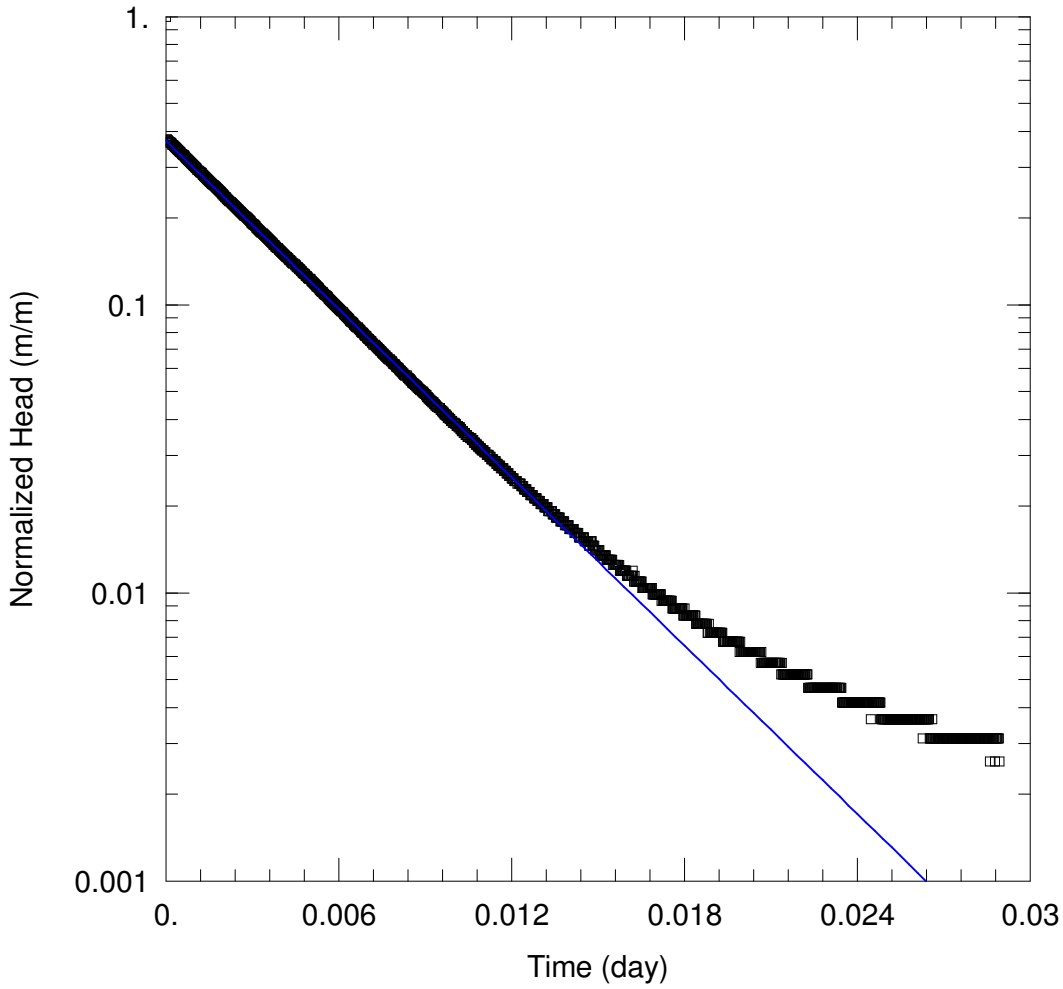
WELL DATA (DW7220W2)

Initial Displacement: 19.43 m
Total Well Penetration Depth: 18.97 m
Casing Radius: 0.025 m
Static Water Column Height: 18.97 m
Screen Length: 6. m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.01219 m/day
Kz/Kr = 0.1
Ss = 0.02476 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7220W3_Bouwer-Rice.aqt
Date: 09/07/19 Time: 16:57:40

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7220W3
Test Date: 23 August 2019

AQUIFER DATA

Saturated Thickness: 2. m Anisotropy Ratio (Kz/Kr): 0.1

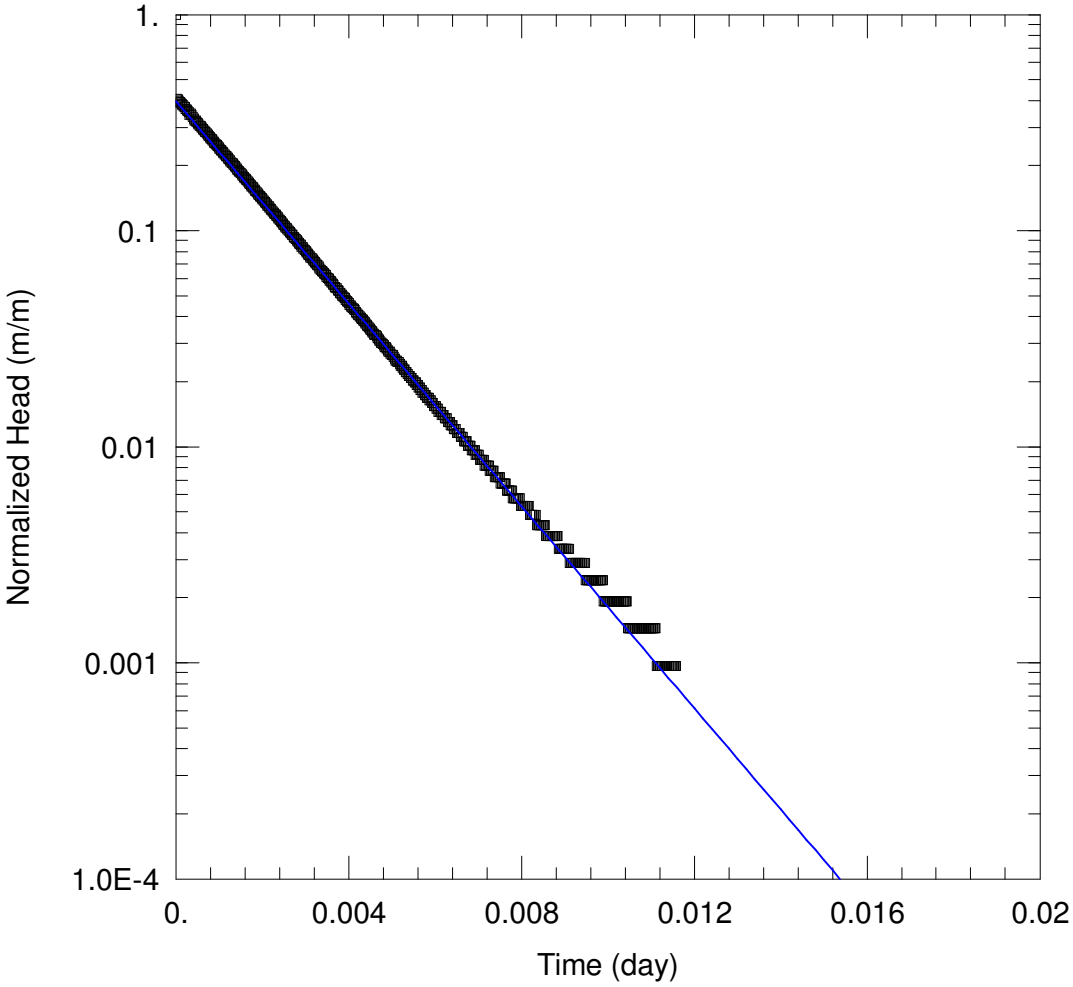
WELL DATA (DW7220W3)

Initial Displacement: 19.23 m Static Water Column Height: 55.81 m
Total Well Penetration Depth: 55.81 m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.293 m/day y0 = 7.131 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7221W1_Bouwer-Rice.aqt
Date: 09/07/19 Time: 17:12:37

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7221W1
Test Date: 23 August 2019

AQUIFER DATA

Saturated Thickness: 3. m Anisotropy Ratio (Kz/Kr): 1.

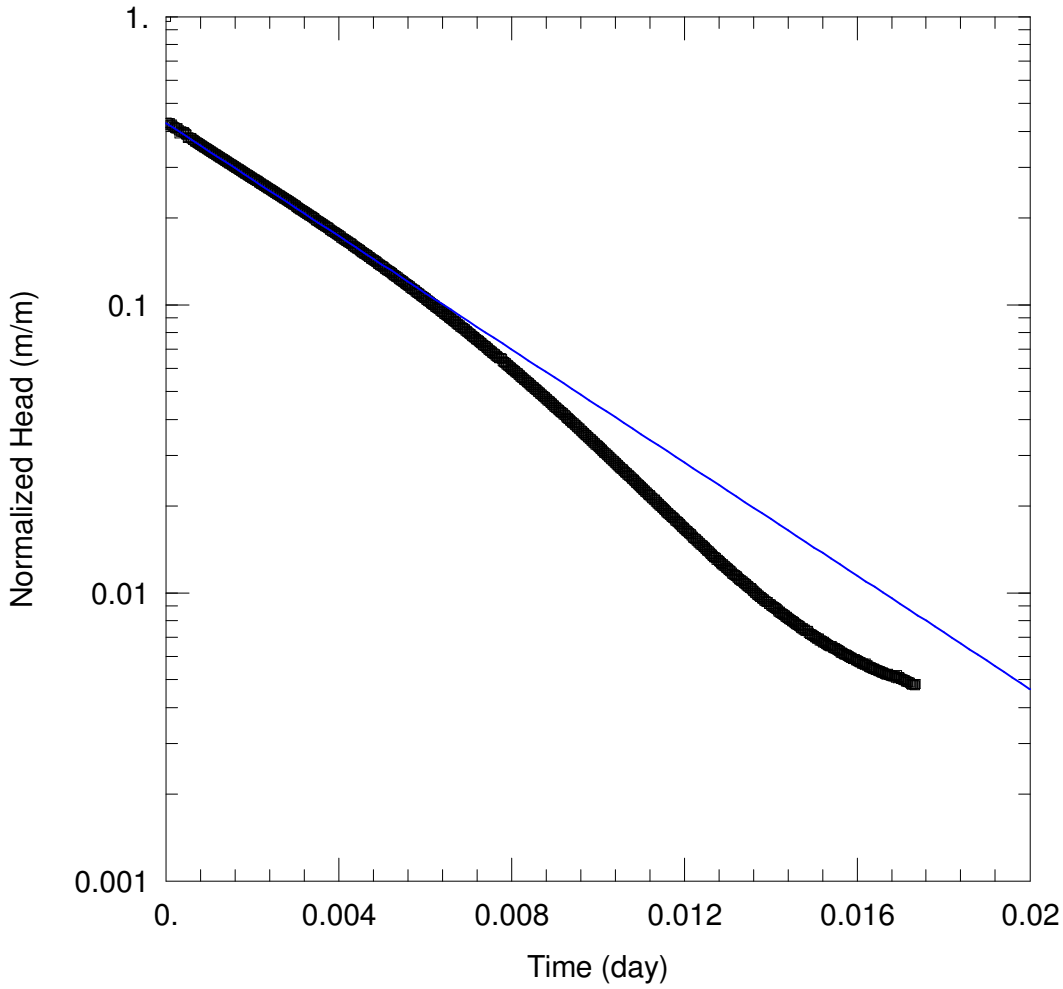
WELL DATA (DW7221W1)

Initial Displacement: 20.72 m Static Water Column Height: 29.71 m
Total Well Penetration Depth: 29.71 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.2859 m/day y0 = 8.245 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7221W2_Bouwer-Rice.aqt
Date: 09/07/19 Time: 17:11:22

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7221W2
Test Date: 23 August 2019

AQUIFER DATA

Saturated Thickness: 2. m Anisotropy Ratio (Kz/Kr): 1.

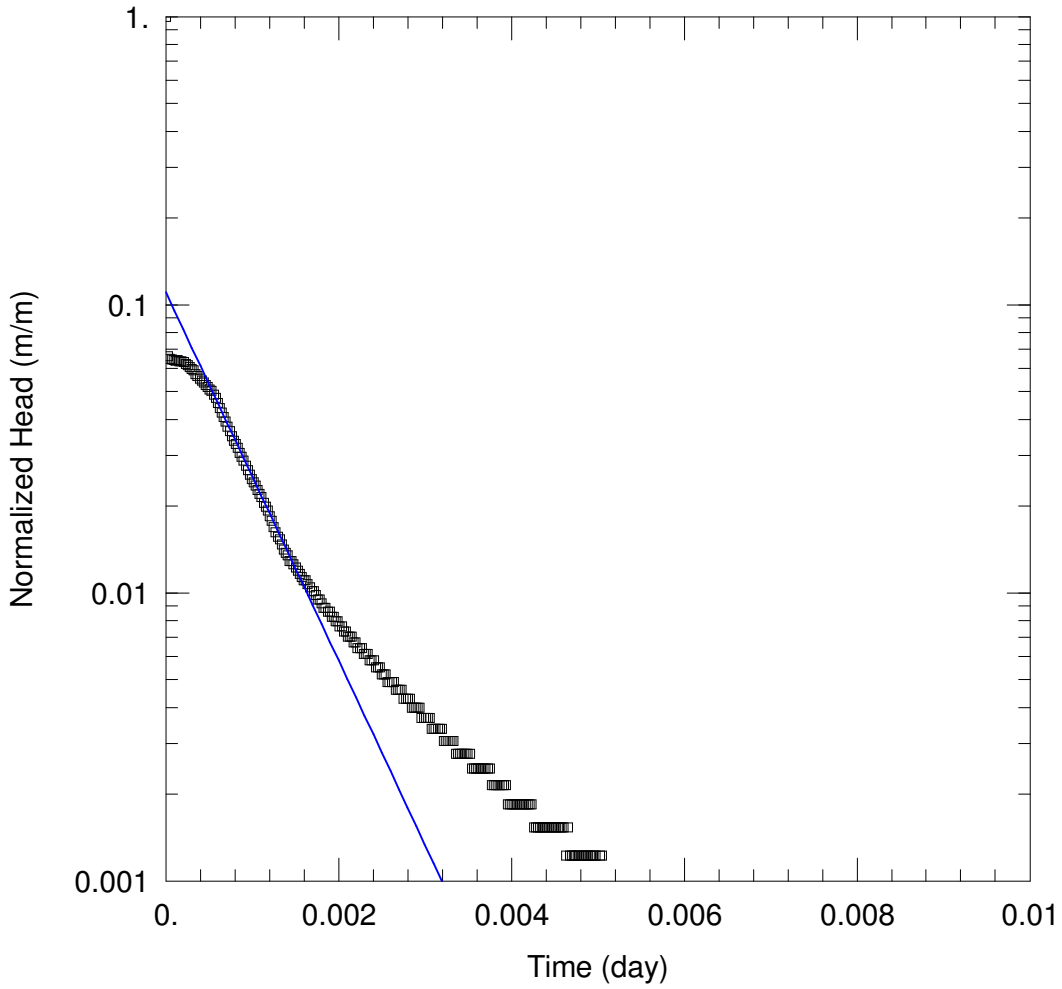
WELL DATA (DW7221W2)

Initial Displacement: 20.77 m Static Water Column Height: 51.59 m
Total Well Penetration Depth: 51.59 m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.2429 m/day y0 = 8.882 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7225W1 Bouwer-Rice.aqt
Date: 09/07/19 Time: 17:14:14

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7225W1
Test Date: 3 September 2019

AQUIFER DATA

Saturated Thickness: 4.37 m Anisotropy Ratio (Kz/Kr): 1.

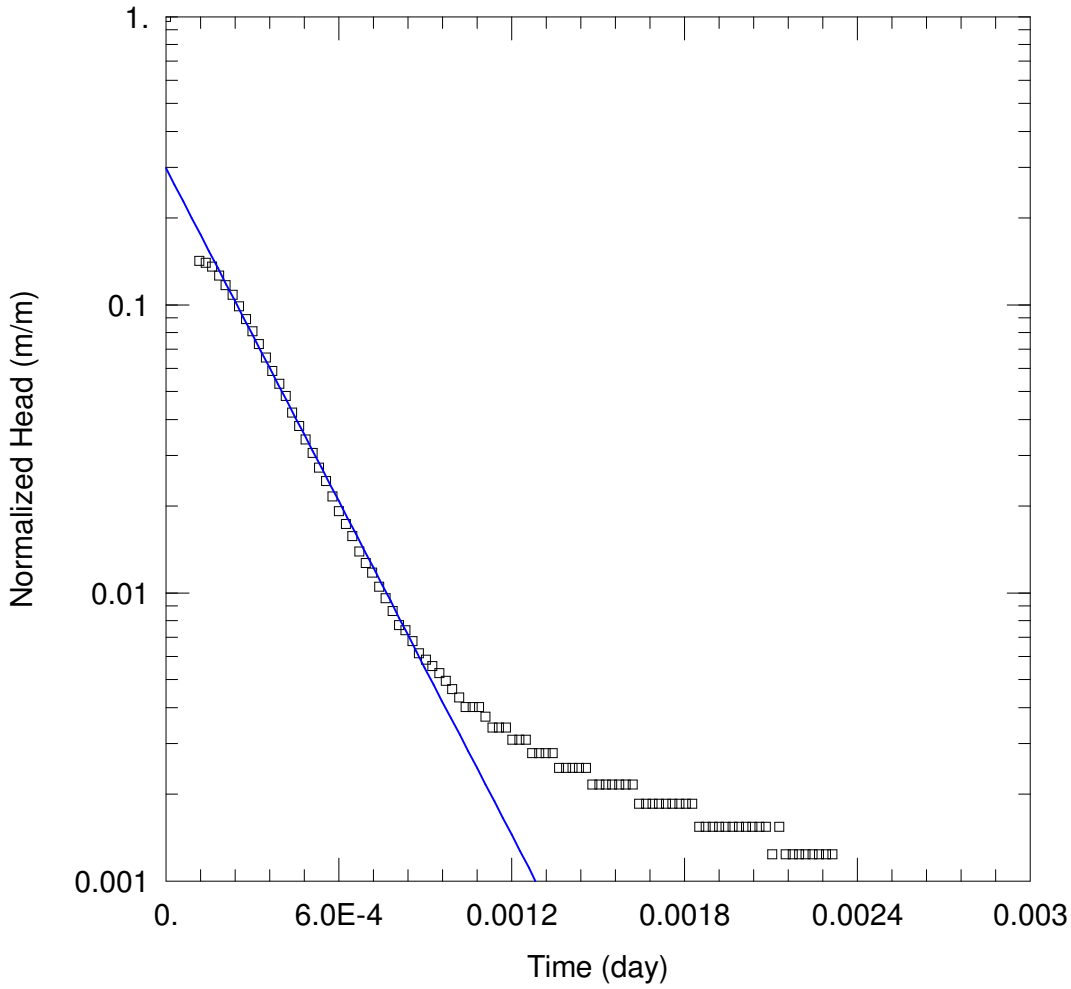
WELL DATA (DW7225W1)

Initial Displacement: 32.63 m Static Water Column Height: 4.37 m
Total Well Penetration Depth: 6. m Screen Length: 6. m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.4438 m/day y0 = 3.6 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7225W2 Bouwer-Rice.aqt
Date: 09/07/19 Time: 17:16:29

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7225W2
Test Date: 3 September 2019

AQUIFER DATA

Saturated Thickness: 3.5 m Anisotropy Ratio (Kz/Kr): 1.

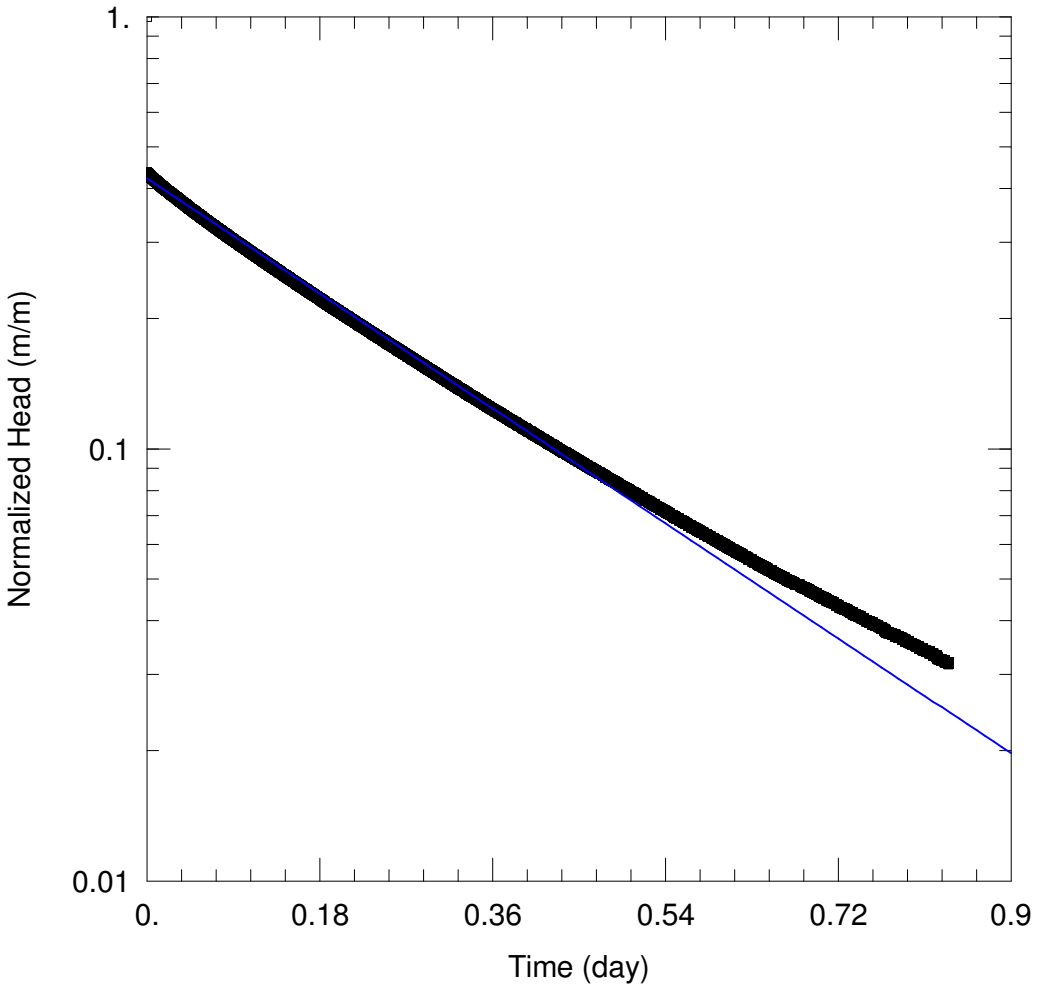
WELL DATA (DW7225W2)

Initial Displacement: 32.37 m Static Water Column Height: 46.53 m
Total Well Penetration Depth: 47.03 m Screen Length: 3.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 2.141 m/day y0 = 9.66 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7225W3 Bouwer-Rice.aqt
Date: 09/07/19 Time: 17:17:59

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7225W3
Test Date: 3 September 2019

AQUIFER DATA

Saturated Thickness: 3. m Anisotropy Ratio (Kz/Kr): 1.

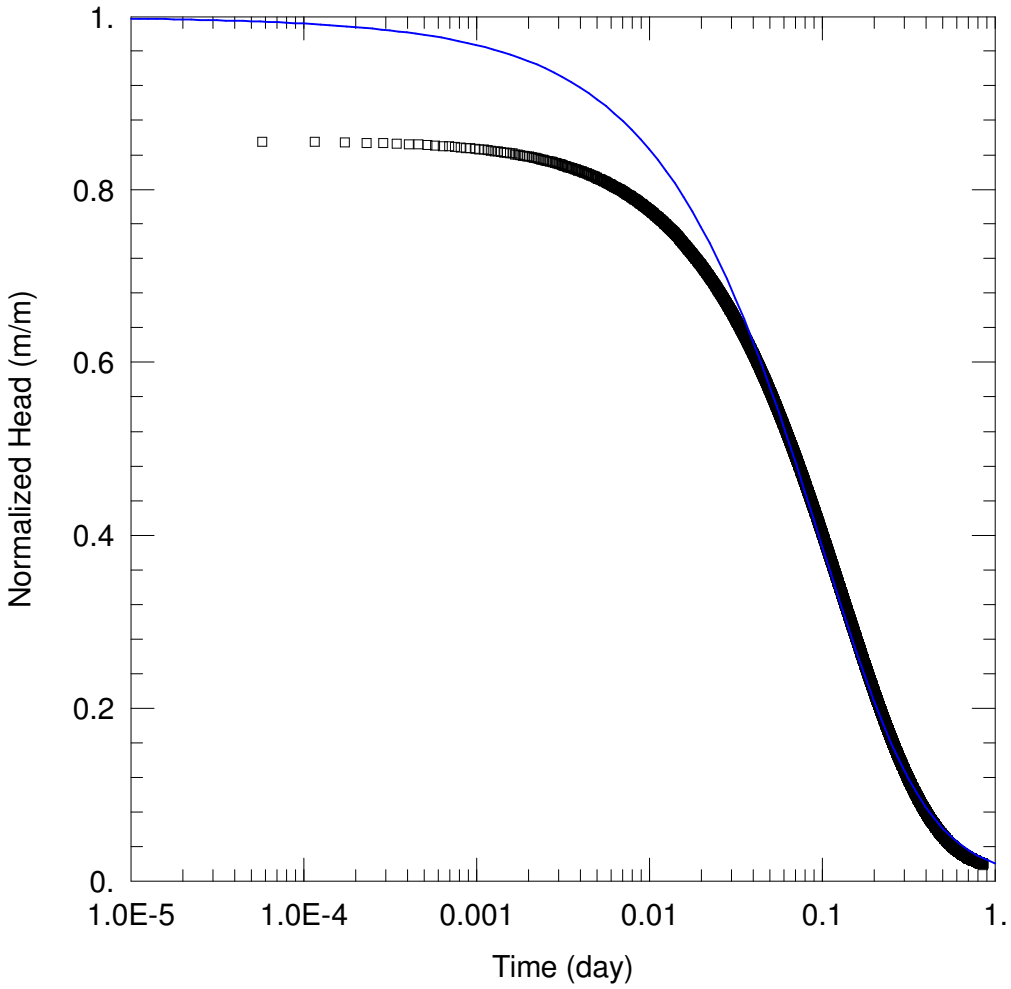
WELL DATA (DW7225W3)

Initial Displacement: 31.84 m Static Water Column Height: 80.96 m
Total Well Penetration Depth: 80.96 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.002001 m/day y0 = 13.44 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7264W2.aqt
Date: 09/07/19 Time: 12:00:13

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7265W2
Test Date: 15 July 2019

AQUIFER DATA

Saturated Thickness: 2. m

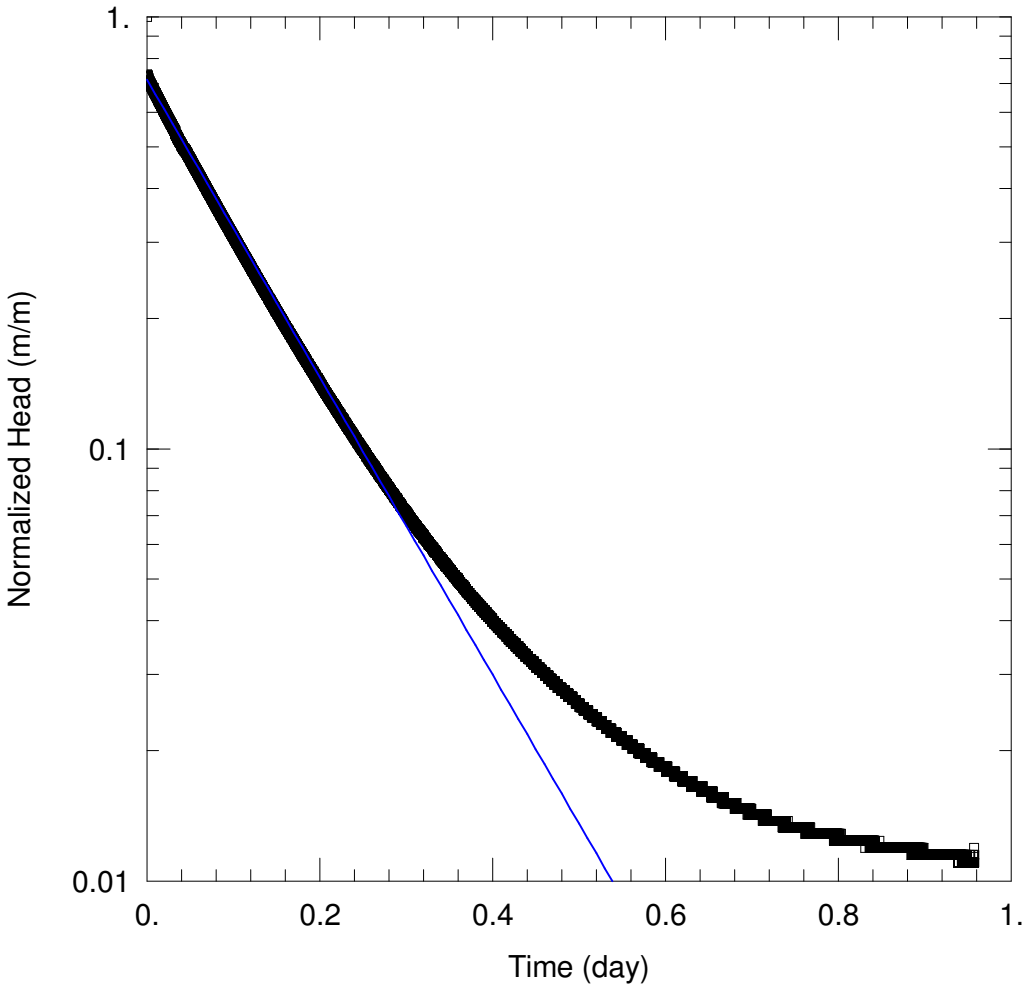
WELL DATA (DW7264W2)

Initial Displacement: 21.77 m
Total Well Penetration Depth: 82.44 m
Casing Radius: 0.025 m
Static Water Column Height: 82.44 m
Screen Length: 1.5 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.009237 m/day
Kz/Kr = 0.1
Ss = 0.006874 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7264W3.aqt
Date: 09/07/19 Time: 12:22:15

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7265W3
Test Date: 15 July 2019

AQUIFER DATA

Saturated Thickness: 2. m Anisotropy Ratio (Kz/Kr): 0.1

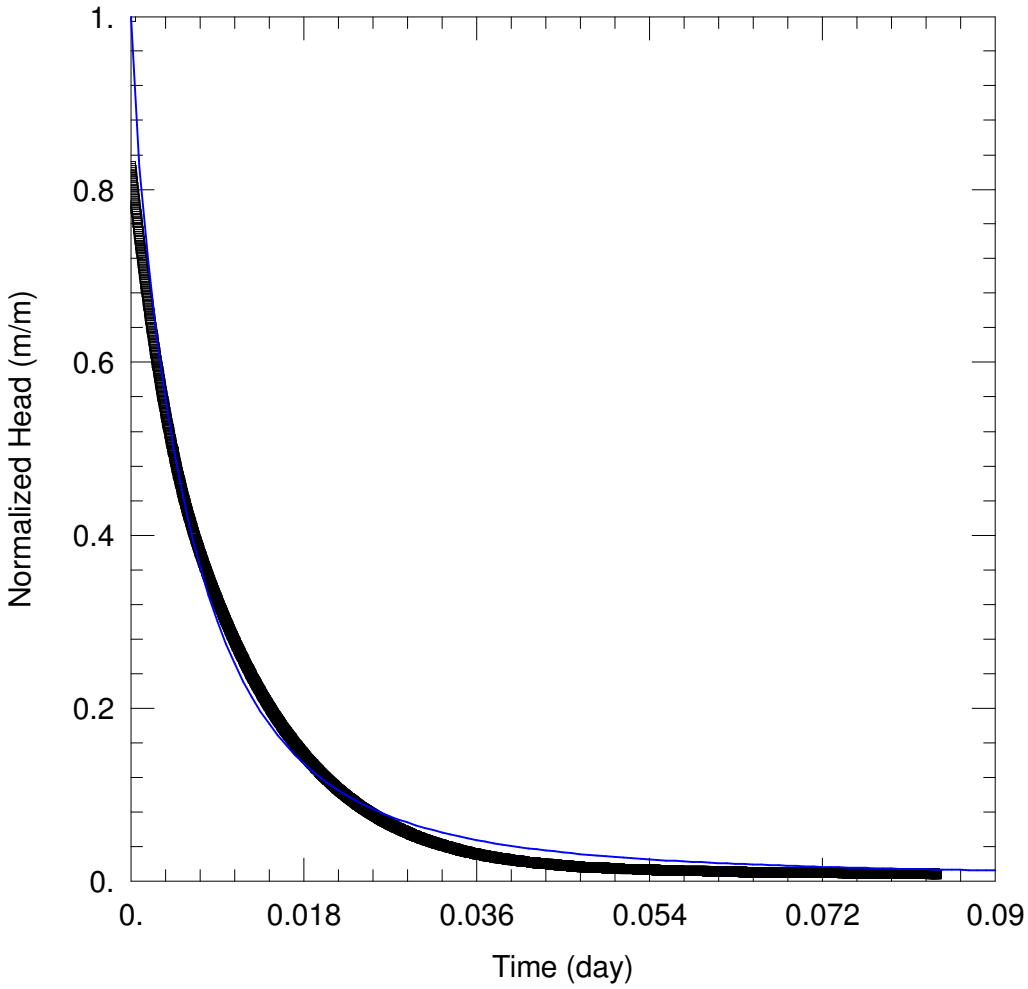
WELL DATA (DW7264W3)

Initial Displacement: 21.78 m Static Water Column Height: 114.9 m
Total Well Penetration Depth: 114.9 m Screen Length: 1.5 m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice

K = 0.01101 m/day y0 = 15.58 m



WELL TEST ANALYSIS

Data Set: D:\...\DW7282W1_KGS Model.aqt
Date: 09/07/19 Time: 14:33:09

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7282W1
Test Date: 18 July 2019

AQUIFER DATA

Saturated Thickness: 16.58 m

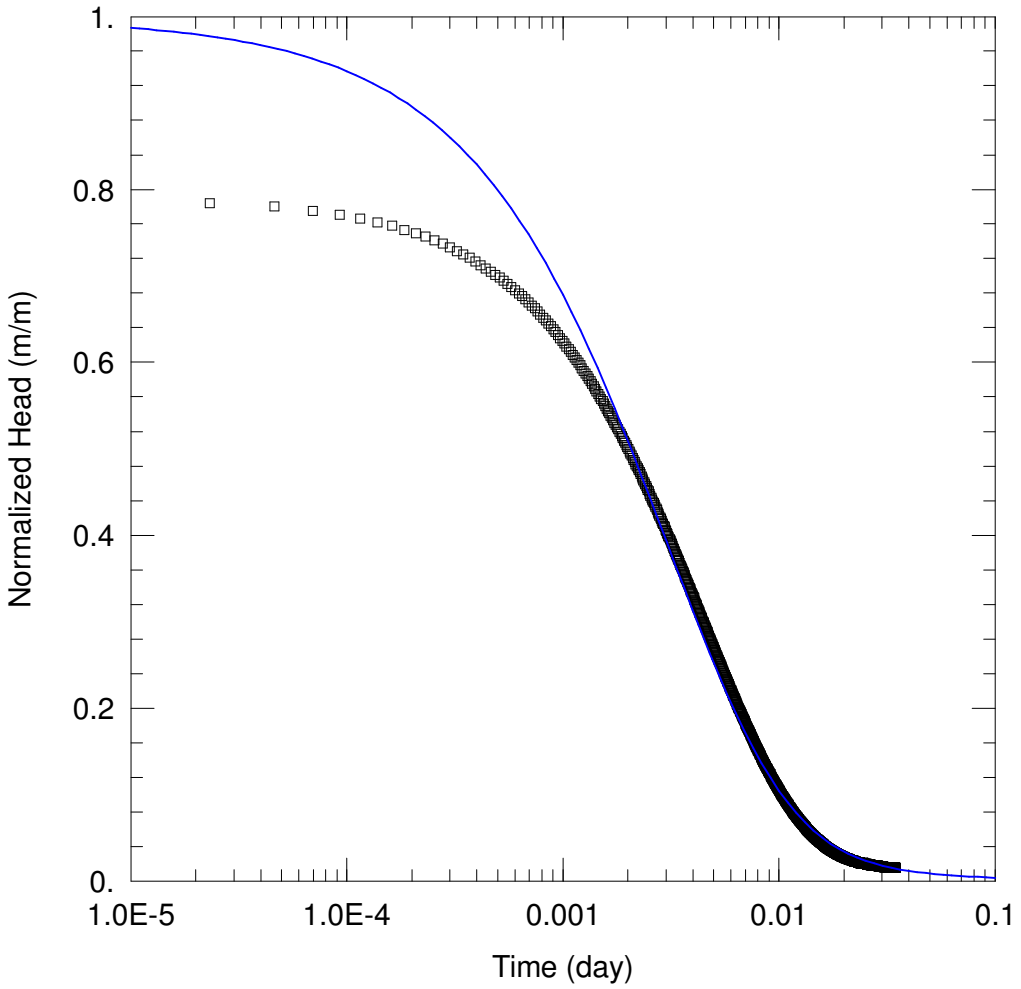
WELL DATA (DW7282W1)

Initial Displacement: 26.45 m
Total Well Penetration Depth: 16.58 m
Casing Radius: 0.025 m
Static Water Column Height: 16.58 m
Screen Length: 6. m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.02744 m/day
Kz/Kr = 0.1
Ss = 0.0003112 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7282W2_KGS Model.aqt
Date: 09/07/19 Time: 14:51:10

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7282W2
Test Date: 18 July 2019

AQUIFER DATA

Saturated Thickness: 2. m

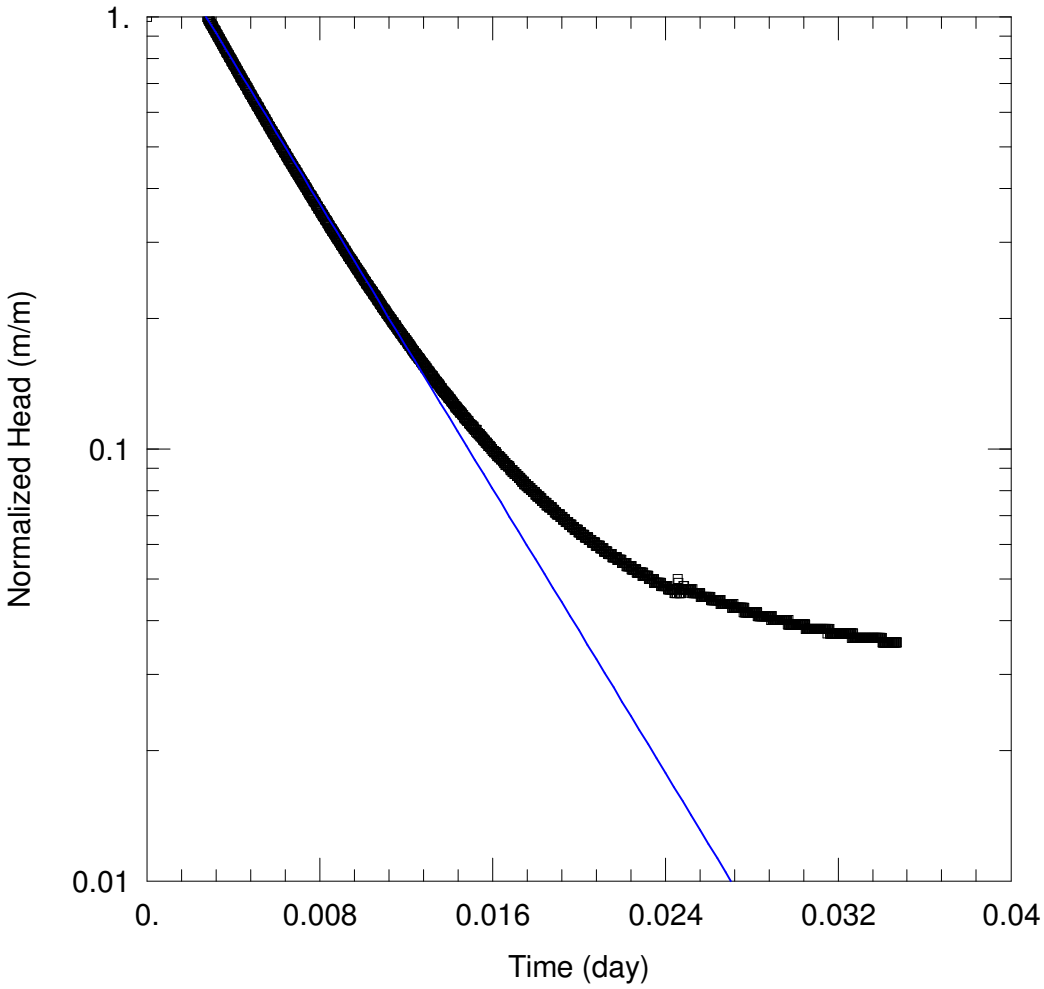
WELL DATA (DW7282W2)

Initial Displacement: 26.51 m
Total Well Penetration Depth: 63.4 m
Casing Radius: 0.025 m
Static Water Column Height: 63.4 m
Screen Length: 1.5 m
Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined
Solution Method: KGS Model

Kr = 0.2446 m/day
Kz/Kr = 0.1
Ss = 0.00214 m^{-1}



WELL TEST ANALYSIS

Data Set: D:\...\DW7291W1.aqt
Date: 09/07/19 Time: 15:07:11

PROJECT INFORMATION

Company: Gemini Project
Test Well: DW7292W1
Test Date: 23 August 2019

AQUIFER DATA

Saturated Thickness: 3.78 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (DW7292W1)

Initial Displacement: 11.22 m Static Water Column Height: 3.78 m
Total Well Penetration Depth: 3.78 m Screen Length: 3. m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 0.09701 m/day y0 = 18.86 m